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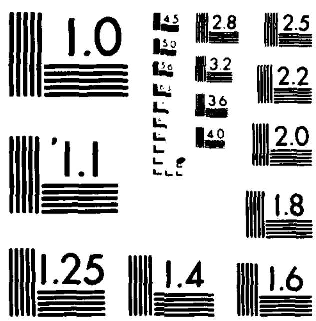

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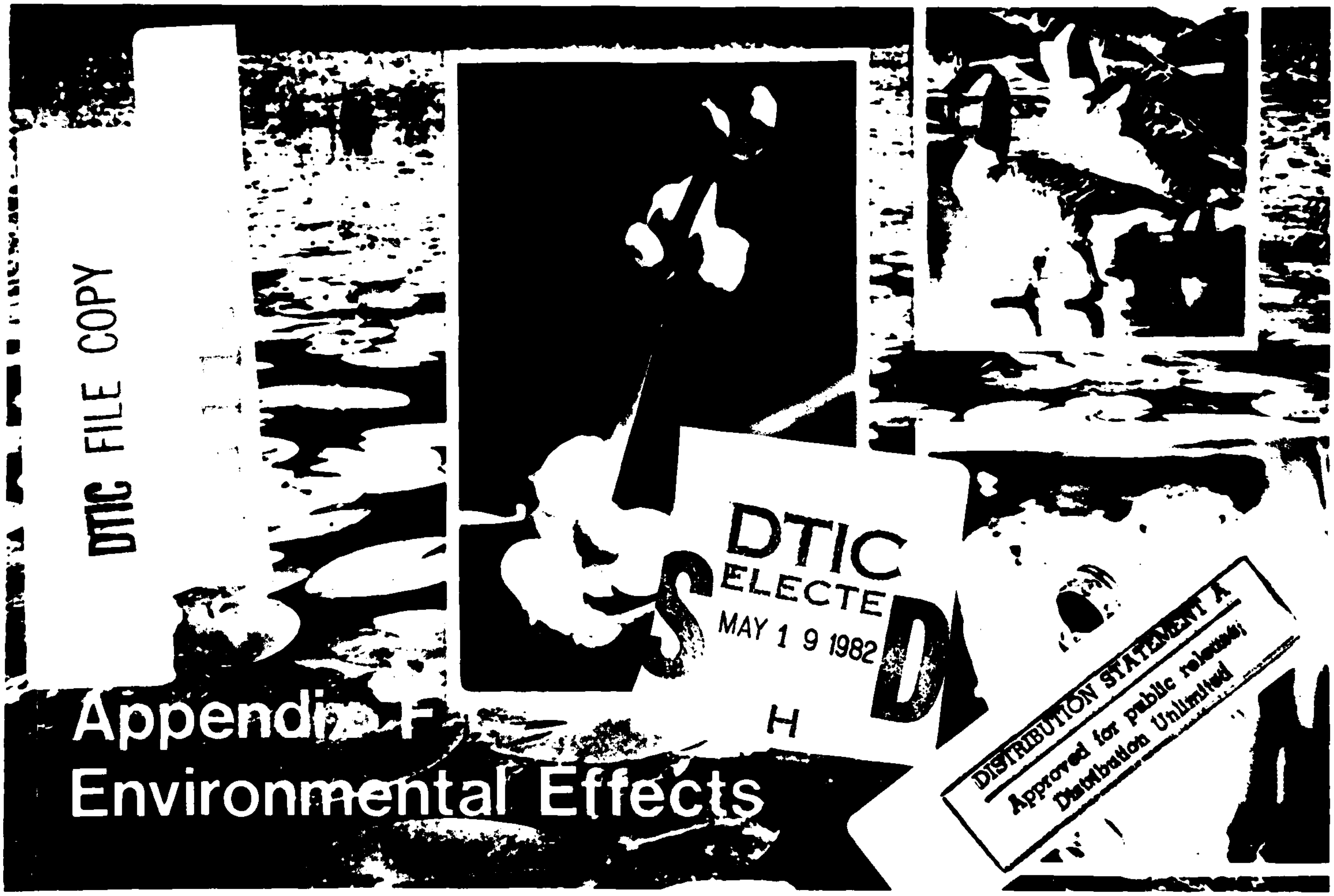

Appendix F
Environmental Effects

International Lake Erie Regulation Study Board
International Joint Commission
July 1981

REPORT DOCUMENTATION PAGE

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This appendix presents the environmental evaluation carried out by the International Lake Erie Regulation Study Board of potential changes in water quality, wildlife and fish resources resulting from limited regulation of Lake Erie. Each of these three areas was generally addressed according to available methodology and data. The results of the evaluations are presented for each lake as potential systemic impacts and for the Niagara and St. Lawrence River as potential structural impacts. → next page

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20. The Water Quality evaluation included an investigation of seven water quality characteristics: turbidity, embayment flushing, change in the size of the hypolimnion, Cladophora growth, phosphorus concentrations, waste water discharge and general water quality.

The wildlife evaluation investigated the effects of the regulation plans on wildlife resources and habitat with respect to systemic, construction and operation induced impacts. Changes in four vegetation zones and seven wetland types were predicted. The effects of habitat changes on wildlife species were also described.

The possible impact of water level regulation on the fish resources was inferred from changes to the wetland communities, changes in water quality characteristics, and some data on relative spawning success of fish which may be influenced by the particular water levels during spawning/incubation.

APPENDIX F

ENVIRONMENTAL EFFECTS

LAKE ERIE REGULATION STUDY REPORT

TO THE

INTERNATIONAL JOINT COMMISSION

BY THE

INTERNATIONAL LAKE ERIE REGULATION STUDY BOARD

(UNDER THE REFERENCE OF 21 FEBRUARY 1977)

JULY 1981

SYNOPSIS

This appendix presents the environmental evaluation carried out by the International Lake Erie Regulation Study Board during its study to determine the possibility of limited regulation of Lake Erie. The study was conducted under the 21 February 1977 Reference to the International Joint Commission by the governments of Canada and the United States.

The environmental evaluation was limited to an evaluation of potential changes in water quality, wildlife and fish resources. Each of these three areas was generally addressed according to available methodology and data. The results of the evaluations are presented for each lake as potential systemic impacts and for the Niagara and St. Lawrence River as potential structural impacts. The Water Quality evaluation included an investigation of seven water quality characteristics: turbidity, embayment flushing, change in the size of the hypolimnion, Cladophora growth, phosphorus concentrations, waste water discharge and general water quality.

The wildlife evaluation investigated the effects of the regulation plans on wildlife resources and habitat with respect to systemic, construction and operation induced impacts. Changes in four vegetation zones and seven wetland types were predicted. The effects of habitat changes on wildlife species were also described.

The possible impact of water level regulation on the fish resources was inferred from changes to the wetland communities, changes in water quality characteristics, and some data on relative spawning success of fish which may be influenced by the particular water levels during spawning/incubation.

The overall impact of water level regulation on the environmental parameters was found to be negative. Generally, seasonal and annual water fluctuations were found to be desirable to maintain the diversity of the wetlands and of the fish population. Extreme highs or lows would be destructive to the wildlife and fish resources through habitat destruction. However, the dividing line between the desirable and the undesirable highs and lows has not been identified and may vary for different locations.

Participants in this environmental evaluation included professional resource managers from the involved Province, State and Federal Governments.

COVER PHOTO: Wye Marsh, Canadian Wildlife Service, Environment Canada.

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A detailed description of the various factors which govern the water supply to the Great Lakes - St. Lawrence River System and affect the response of the system to this supply along with documentation of the development and hydrologic evaluation of plans for limited regulation of Lake Erie.

APPENDIX B - REGULATORY WORKS

A description of design criteria and methods used and design and cost estimates of the regulatory and remedial works required in the Niagara and St. Lawrence Rivers to facilitate limited regulation of Lake Erie.

APPENDIX C - COASTAL ZONE

A documentation of the methodology developed to estimate in economic terms the effects of changes in water level regimes on erosion and inundation of the shoreline and water intakes and of the detailed economic evaluations of plans for limited regulation of Lake Erie.

APPENDIX D - COMMERCIAL NAVIGATION

A documentation of the methodology applied in the assessment of the effects on shipping using the Great Lakes - St. Lawrence navigation system as a consequence of changes in lake level regimes and the evaluation of the economic effects on navigation of regime changes that would take place under plans for limited regulation of Lake Erie.

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Section 1

INTRODUCTION

Cognizant of the many problems caused by recent high lake levels, the Governments of the United States and Canada requested the International Joint Commission in 1977 to study the possibilities for limited regulation of Lake Erie. Because of the far-reaching effects of regulation, the study was broken down into many different components. The objective of the environmental studies was to provide information on the environmental benefits and losses of regulation as input to the overall feasibility evaluation. This included the analysis of site-specific effects of regulatory works in the Upper Niagara River and remedial works in the St. Lawrence River.

The environmental impact of limited regulation of Lake Erie could be very broad, including impacts on water quality, wetlands/ wildlife, and fish. This appendix contains, for each of these subject areas, the evaluation of the effects of water level and outflow changes due to three regulation plans (Plans 6L, 15S and 25N) in the lower Great Lakes study area from Port Huron, Michigan-Sarnia, Ontario to the New York State - Prvince of Quebec border. This included examination of the effects of the construction and operation of the regulatory works in the Niagara River and Black Rock Canal. It also involved evaluation of the environmental implications of remedial works in the St. Lawrence River.

The types of water level/flow changes due to the plans and the structural considerations which are pertinent to the environmental evaluation are presented in Section 2.

All of the environmental subject areas were concentrated on Lake Erie and Lake St. Clair as they tend to be most severe on these lakes. The systemic evaluations focused mainly on the nearshore where effects of regulation would be most visible and measurable than these in the open Lake. The evaluations of structural effects placed emphasis on the Niagara and St. Lawrence Rivers, where the regulatory and remedial works would be located. The evaluations varied from quantitative to qualitative, governed by knowledge in the subject area and availability of existing pertinent data.

The evaluation of the effects of limited regulation of Lake Erie on water quality (Section 3) was quantitatively, since it showed the probable changes in water quality parameters for specific situations. The evaluation of the effects on wildlife/wetland (Section 4) tend to be qualitative, and involved examining changes in habitat that would occur as a result of altered lake level regimes. Attention was focussed on wetlands since these comprise the primary type of wildlife habitat on the Great Lakes. The evaluation analyzed responses of wetland vegetation to altered lake levels and, based on the habitat requirements of various wildlife species, made general predictions concerning the effects of regulation on these species.

The fish evaluation (Section 5) attempted to delineate, in qualitative terms, the directions and general patterns of change which would result from limited regulation of Lake Erie. The systemic effects were derived by evaluating the impacts of long-term water level changes due to regulation in critical nearshore areas, particularly the productive shallow water environments and wetlands, and on species sensitive to alterations in water level and flow.

Structural evaluations of the Niagara River alternatives were based on criteria for selection of the least-detrimental alternative.

In the St. Lawrence River the probable environmental impacts of the channel enlargements were more difficult to define due to a relatively sparse environmental data base. In this area, only the nature of the probable effects due to channel enlargements were identified.

Owing to time and resource constraints, the analysis was preliminary in nature. Observations were often drawn from an insufficient data base, resulting in qualitative assessments in some areas. The effects identified through this analysis would have required a full investigation had limited regulation of Lake Erie been demonstrated to be economically feasible.

In most cases, the metric units of measurement are used in this appendix. An English/metric conversion table is annexed to the appendix (Annex 12). Annex 11 is a list of participants in the environmental study. Annex 10 lists the literature cited.

Section 2

REGULATION PLAN EFFECTS ON WATER LEVELS/FLOWS IN THE LOWER GREAT LAKES

2.1 General

The historical lake level regime has shaped the present day Great Lakes environment. The existing state of water quality, wildlife/wetland and fish resources are the products of the recent historical water level fluctuation patterns and other environmental conditions, particularly of the last 20 years.

Based on the analysis of recorded water levels and review of pertinent literature, the characteristics listed below were identified as important in bringing about the existing environment:

1. long-term mean water level;

2. extreme high and low water levels (their frequency of occurrences and durations);

3. long-term water level fluctuation range; and

4. seasonal distributions and timing of high and low water levels (i.e., annual low water levels in January/February; the rising water levels during spring; and the amplitude of this seasonal fluctuation).

All three regulation plans (25N, 15S and 6L) to some degree would affect these water level characteristics and thereby, the environment.

In the wildlife/wetland and fish evaluations the magnitude of the change in water level conditions from basis-of-comparison (BOC) were examined. The anticipated impacts were then described qualitatively in terms of their nature and significance.

The seasonal and long-term water level fluctuations are important in the water quality evaluation. However, they were examined in a somewhat different fashion. The water quality analysis looked at changes in chemical, physical and biological processes in the Great Lakes as a result of varying water levels. Each water quality characteristic was treated separately depending upon the nature of the characteristic and the amount and quality of the baseline data available. Any water quality changes which might be caused by regulation were viewed in comparison to the range of seasonal and year-to-year quality characteristics which would be experienced under the BOC water level condition. Hypolimnion quality and quantity, nearshore turbidity and Cladophora production were viewed in this context. Secondly, for embayment flushing and waste outfall dispersion, any water quality changes were assessed in light of worst-case scenarios.

2.2 Basis-Of-Comparison (BOC)

The basis-of-comparison (BOC) and adjusted basis-of-comparison (ABOC) represent the water levels and outflows that the Great Lakes would have experienced for the study period 1900-1976 under certain assumed conditions. They also portray water levels which could occur in the future if the Great Lakes were to experience supplies similar to those received for the period 1900-1976. The BOC and ABOC levels, therefore, are distinctly different from the historical 1900-1976 water levels. They are anticipated future levels forming a basis from which deviations caused by regulation could be measured and evaluated. The historical conditions which occurred during the 77 year period have been used only as indicators of how recent conditions have shaped the existing environment.

Annexes 5 and 6 contain the results of the hydrologic evaluations carried out in this study. Appendix A-Lake Regulation and Section 3 of the Main Report provide detailed descriptions of the development of the basis-of-comparison and adjusted basis-of-comparison. Table F-1 is a summary of the hydrologic evaluation of Lake Erie regulation plans.

Limited regulation of Lake Erie would require construction of regulatory works at the head of the Niagara River. These works would be operated, when required, to permit additional Lake Erie outflows. Their capacities range from low, such as Plan 6L which uses the Black Rock Lock, to high, such as Plan 25N which uses the Niagara River structure.

2.3 Lakes Erie and St. Clair

2.3.1 Plan 25N

Plan 25N would require a control structure in the Niagara River that would provide an additional outflow capacity of 25,000 cfs. It would lower the mean level of Lake Erie by about 7 inches. It would have the most dramatic effect of all the plans on water levels. The plan would increase the frequency of occurrences of low levels. This could have considerable impact on the warm water fishes in areas such as Long Point Bay. The plan would also reduce the frequency of occurrences of highs levels. The plan would not produce any noticeable changes in the seasonal water level pattern.

For the high water period (years 1971 to 1976) the plan would reduce the Lake Erie mean level averaged for those years by about 12 inches and the maximum June mean level also by about 12 inches. During the low water period (1961 to 1966) this plan would lower the mean level for Lake Erie by 4 inches and the minimum February mean level also by 4 inches. The duration of low water periods would be increased.

On Lake St. Clair, Plan 25N would lower the mean level by 5 inches. For the low water years (1961 to 1966) the plan would reduce the Lake St. Clair mean level for the period by about 3 inches.

TABLE F-1 Summary of Hydrologic Evaluation of Lake Erie Regulation Plans

	Basis-of-Comparison	Plan 6L	Plan 15S	Plan 25N
LAKE SUPERIOR				
Mean	600.44	600.43	600.41	600.37
Maximum	601.93	601.93	601.93	601.93
Minimum	598.69	598.68	598.65	598.62
Range	3.24	3.25	3.28	3.31
LAKES MICHIGAN-HURON				
Mean	578.27	578.24	578.18	578.05
Maximum	581.15	581.09	580.99	580.75
Minimum	575.47	575.45	575.42	575.36
Range	5.68	5.64	5.57	5.39
LAKE ERIE				
Mean	570.76	570.67	570.53	570.17
Maximum	573.60	573.45	573.18	572.53
Minimum	568.09	568.07	568.02	567.84
Range	5.51	5.38	5.16	4.69
LAKE ONTARIO-CAT. 1 (with deviation)				
Mean	244.61	244.64	244.65	244.63
Maximum	247.37	247.39	247.56	247.50
Minimum	241.81	241.74	241.59	241.38
Range	5.56	5.65	5.97	6.12
LAKE ONTARIO-CAT. 2				
Mean	244.61	244.66	244.69	244.71
Maximum	247.37	247.34	247.42	247.45
Minimum	241.81	242.04	242.12	242.21
Range	5.56	5.30	5.30	5.24

	Adj. B.O.C.	Plan 6L	Plan 15S	Plan 25N
LAKE ONTARIO-CAT. 3				
Mean	244.63	244.64	244.65	244.67
Maximum	246.77	246.79	246.84	246.83
Minimum	242.38	242.32	242.34	242.47
Range	4.39	4.47	4.50	4.36

2.3.2 Plan 15S

Plan 15S would require a Black Rock Canal-Squaw Island Diversion Channel structure to increase the outflow capacity by about 10,000 cfs. It would lower the Lake Erie mean level by about 3 inches. During high water period (1971 to 1976) this plan would reduce the Lake Erie mean level for the period by about 4 inches and the maximum June level by 5 inches. It would reduce the frequency of occurrences of high levels but would also increase the frequency of occurrences of low level. During low water years (1961 to 1966), the plan would lower the Lake Erie mean level by about 2 inches and the minimum level also by about 2 inches. For Lake St. Clair, the long-term mean level would be lowered by about 2 inches.

2.3.3 Plan 6L

Plan 6L would require modifications to the existing Black Rock Navigation Lock to increase the outflow capacity by about 4,000 cfs. It would lower the Lake Erie mean level by about 1 inch. There would be slight changes in the frequency of occurrences of high and low water levels.

2.4 Lake Ontario

On Lake Ontario the long-term mean water level would not change much under Category 1. For Category 2 plans, they would be increased slightly. Compared to the adjusted basis-of-comparison, Category 3 plans would raise slightly the mean level. All three plans would increase the frequency of occurrences of high levels. All plans under Category 1 would lower the minimum water levels, an effect which was particularly noticeable during extended low periods (1961 to 1966). The long-term fluctuation range would be increased slightly for all plans under Category 1.

Section 3

WATER QUALITY

3.1 Introduction

The maintanence and enhancement of water quality in the Great Lakes are essential to social and environmental interests. Water quality is generally described in terms of chemical, physical, and biological characteristics. Limited regulation of Lake Erie could have both adverse and beneficial impact on these characteristics locally and on a system wide basis. Structures required for regulation could cause site specific environmental problems related to construction and operation.

Water quality characteristics that could be affected by regulation include hypolimnion, nearshore turbidity, embayment dilution capacity, Cladophora production, waste outfall dispersion, total phosphorus budget, and general water quality.

The hypolimnia (which are the bottom layers during periods of thermal stratification) of both Lakes Erie and Ontario are important havens for cold water fish in late summer and early autumn when the warmer epilimnia (upper layers) would present stress to such fish. Regulation could affect the size of the cold water fish habitat in the summer, the hypolimnion dissolved oxygen concentration, temperature, the onset of stratification, and the total dissolved oxygen reserves.

Turbidity reflects the amounts of suspended materials in the water. Apart from aesthetics, turbidity concentrations affect the degree of water treatment. Shoreline erosion and basin tributaries are the major contributors of sediments to the nearshore zone. Dredging and landfilling operations also are sources of suspended sediments and can engender water quality problems in the areas dredged and further downstream. To the extent that many toxicants and nutrients adsorb to the finer fractions of sediments, control of sediments both from erosion and tributary sources has recently received much attention from various researchers and government agencies.

Limited regulation of Lake Erie might also affect embayment flushing and dilution characteristics. Reduction in embayment flushing and dilution capacity could increase pollutant concentrations.

A prominent aquatic plant is the attached alga Cladophora which grows in ever-widening areas in shallow water along the shores of the lower lakes and contributes to the degradation of shoreline aesthetics and perhaps property values. Changes in substrate area and light availability, both impacted by regulation, could affect Cladophora growth. Water clarity and freedom from nuisance algae are desirable and enhance property values of the shoreline, as well as such recreational activities as swimming and boating.

Low lake levels would decrease the nearshore water available to dilute waste discharges and possibly expose previously submerged outfall heads thereby contributing to aesthetic problems.

Limited regulation of Lake Erie generally could affect residence times and the quantitative character of lake dilution capability, thus affecting changes in the overall general water quality of the system.

3.2 General Approach

The effects of limited regulation of Lake Erie on water quality were evaluated with regard to the following:

1. Site Specific Effects from Structures arising from the construction and operation of regulatory works in the Niagara River or the Black Rock Canal, and Channel enlargements in the St. Lawrence River; and

2. Systemic Effects arising from the potential changes in physical, chemical, and biological processes in the Great Lakes.

With respect to works, velocity changes in the Niagara River and Black Rock Canal have been examined. The resultant scouring and downstream transport of bed load has been addressed.

With respect to systemic effects, the physical, chemical and biological lake processes dependent upon available depth of water. The lake level changes due to regulation would be rather small (with the most extreme plan, Plan 25N, the average lowering of Lake Erie level would be 0.6 feet and maximum lowering would be about 1.1 feet). It appears that any potential changes in lakewide water quality could be rather minimal. It should also be noted that, since most water uses occur in the nearshor areas of the lake, any changes in quality of nearshore water would be generally more noticeable than changes in the mid-lake.

In light of the above, and since the nearshore is the most important lake area for fish production and habitat, wildlife, and human activities, the water quality study placed emphasis on these areas. Water quality characteristics that were evaluated in this study are listed below together with the rationale for their selection.

1. Volume and dissolved oxygen concentrations in the hypolimnion and onset of stratification. Volume of hypolimnion is influenced by depth of lake.

2. Nearshore turbidity. Lowered lake levels reduce waves reaching the bluffs, reducing erosion thus decreasing turbidity.

3. Embayment dilution capacity. Ability of embayment to exchange water with the lake and

volume of embayment water available for dilution purposes are affected by water depth.

4. Cladophora production. Production is a function of available substrate and turbidity, both of which are affected by lake level changes.
5. Phosphorus concentration resulting from shore erosion. The amount of phosphorus contributed to Great Lakes waters will be reduced as a result of reduced shoreline erosion.

The water quality analysis presented herein attempted to delineate, in qualitative and quantitative terms, the directions and general pattern of changes as a result of regulation. The evaluation of the effects on water quality in Lake Ontario and the St. Lawrence River was based on Category 2 and 3 plans.

For any given regulation plan, the manner and magnitude of changes in water quality may differ substantially. Since there is much variability in the available data defining each water quality characteristic, it was necessary to treat each separately and to employ a different methodology and information base for each analysis.

Two analytical approaches to assessment have been utilized in this study, the approach used depending upon the nature of the characteristic evaluated. Some regulation induced changes were examined relative to the range of seasonal and annual water quality changes experienced under the BOC conditions. Hypolimnion quality and quantity, nearshore turbidity and Cladophora production were viewed in this context. Secondly, for some characteristics (i.e., embayment dilution capacity and waste outfall dispersion), the water quality change was assessed in light of worst-case scenarios, that is, the change could represent added stress under conditions when the quality of the ambient environment was already in a critical state. Table F-2 illustrates the methods and various assumptions employed.

3.3 Hypolimnion

3.3.1 Existing Regime

Thermal inputs by solar radiation on the water surface contribute to the heat budget of large lakes (Wetzel 1975). On the Great Lakes these thermal inputs comprise a major portion of all heat inputs. As the Great Lakes warm in the spring, a band of warm water called a thermal bar expands from the shoreline toward the center of the lake. Eventually, the lakes completely stratify with three distinct thermal zones: epilimnion, metaliminion (thermocline), and hypolimnion. The epilimnion is the warm upper layer whereas the hypolimnion layer is the cooler bottom layer.

General Approach for Evaluation of the Impacts on Water Quality

Parameter/ Process	Procedure	Major Assumptions: General	Major Assumptions: Technical	Data Base: Geographic Coverage	Data Base: Temporal Coverage	Data Gaps
Hypolimnion	Linear regression technique (Oxygen depletion rate is a function of hypolimnion thickness)	Change in lake level equals change in hypolimnion thickness	- Constant hypolimnion temperature - Only hypolimnion thickness affects oxygen depletion	Lake Erie - Eastern and Central Basins	Eleven summer months between 1960 and 1977	Require BOC hypolimnion thickness for analysis
Turbidity	Linear regression model (turbidity is a function of lake level, toe-of-bluff wave and season)	Nearshore turbidity caused by shoreline erosion and bottom sediment resuspension	- Shoreline erosion a function of toe-of-bluff wave energy	Lake Erie - Port Stanley area and Ohio State area Lake Ontario - Grimsby area	Computer simulations of monthly turbidities for 1967-1976	Limited to data at WTP intakes No transposing of equations between reaches
Embayments	Simulate water exchange between lake and embayment plus consider reduced embayment volume	Embayments have vertical side slopes and unrestricted inlets.	- Embayments are instantaneously mixed box models - Hourly levels dominate exchange process	Lake Erie - Mentor, Lorain, and Dunkirk Harbours and Lake Ontario - Hamilton Harbour	Computer simulations of water exchange at LWD and below LWD	Not appropriate for marshes or embayment complexes
Cladophora	Annual production is a function of suitable substrate area	Nuisance and costs due to Cladophora is proportional to production	- Nutrients are not limiting - Production not influenced by turbidity - Yields remain constant	Lake St. Clair - lakewide Lake Erie - Bass Islands area and North Shore of Eastern Basin Lake Ontario - North Shore, east of Toronto	Annual production calculated for 1900 to 1976	
Waste Outfall Dispersion	Empirical Model Dispersion is a function of outfall depth	Only initial dilution affected. Conservative element considered for worst estimate	- Transpose laboratory results to lake conditions	Lake St. Clair - one outfall	Decrease in dispersion studies for 1-foot level decrease increments	
Phosphorus	Empirical Model P concentration a function of loading, water level, and flow	Total phosphorus reflects eutrophication	- Define nearshore zone by 10-metre contour - Retention coefficient proportional to lake level	Lake Erie - nearshore and lakewide Lake Ontario - nearshore and lakewide	1976 conditions examined with and without regulation	
General Water Quality	Empirical formulation	Conservative element observed under worst case conditions	- Chloride is totally conservative - Present pollutant loadings remain constant	Lake Erie - lakewide	Minimum and maximum range of flows, levels, and retention times	
General Water Quality	NOAA hydraulic transient model	Erosion and Dilution are only impacts	Erosion proportional to mean velocity	St. Lawrence River, Kingston to Cornwall	Maximum increase and decrease from mean monthly BOC flows	Modification of channel cross section due to dredging not defined
General Water Quality	Bottom sediment scour a function of water velocity	Contaminated sediments in Black Rock Canal	- Resuspension of bottom sediments proportional to mean velocity	Niagara River and Black Rock Canal	During construction and operation of structures	Insufficient bottom sediment data

Table F-2

Research studies of the Lake Erie hypolimnia have identified variations in hypolimnion thickness, the oxygen depletion rate and anoxic area, both seasonally and annually (Burns and Ross 1972, Charlton 1979, Dobson and Gilberston 1971). The area of anoxia has been a subject of intensive investigation. Anoxia is defined to occur when the dissolved oxygen concentration is less than 1.0 mg/l (International Joint Commission, 1978). Table F-3 shows the estimated anoxic area corresponding to mean June water levels. Note that when water levels were highest in 1973 the greatest anoxic area was recorded.

3.3.2 Implications of Water Level Fluctuations

The hypolimnion is a refuge for cold water fish in summer and autumn when the warmer epilimnion temperatures present stress to such fish. Regulation could affect a number of conditions: the size of the cold water fish summer habitat; decrease the total hypolimnion dissolved oxygen reserves; alter the natural hypolimnion temperature regime; and, hasten the onset of stratification, all impacts having the potential for affecting the cold water fishery.

Limited regulation of Lake Erie would cause less than a two percent reduction in the surface area of Lake Erie (Guppy 1979). This small change in surface area would not appreciably change the net vertical heat flux into Lake Erie. Changes to the Lake Erie heat budget due to its altered outflow and inflow would be too insignificant to warrant consideration. Since it is the solar heat flux on the surface which dominates the heat budget of the lake, the epilimnion and metalimnion volumes would remain essentially unchanged. Thus if the lake is shallower due to lake level regulation and the epilimnion and metalimnion volumes are unchanged, the hypolimnion would be reduced.

For the purpose of this analysis, the lowering of lake level by any amount considered in regulation was assumed to cause a corresponding reduction in the hypolimnion thickness. A correlation of eleven years of recorded Lake Erie mean June water levels and Central Basin hypolimnion thicknesses indicates that lower June water levels usually coincide with reduced hypolimnion thickness. Due to the limited data, no statistically significant relationship between lake level and hypolimnion thickness was derived. The development of a firm relationship was not practical, since climatic conditions (i.e., winds, sunshine hours, temperature, etc.), light attenuation due to biological growth, and lake morpohometry dominate the stratification process.

3.3.3 Methodology

The following concerns have been examined in this study:

1. change of hypolimnion volume;
2. dissolved oxygen concentration; and
3. onset of stratification.

A depth-area curve (hypsographic curve) for Lake Erie (Fig. F-1) was plotted from 1966 data (Robertson and Jordan 1977). The depth-area curve was employed to produce a functional relationship between water column height and lake volume (Table F-4). The water column height/volume relationship was resolved for Lake Erie into the three major basins.

Assuming horizontal stratification, the volume of the hypolimnion for each basin was calculated from Fig. F-2, based upon hypolimnion thickness.

Charlton (1979) uses regression techniques to investigate the relationship between hypolimnion thickness and dissolved oxygen depletion rates. The following relationship, which is applicable only to the Central Basin of Lake Erie, was developed:

$$\underset{[\text{mg/L/mo}]}{\text{Apparent Oxygen Depletion}} = 6.07\ \underset{[\text{metres}]}{(\text{Hypolimnion Thickness})}^{-0.56}$$

According to the model, a reduction in hypolimnion thickness would result in an increase in the oxygen depletion rate within the hypolimnion. Using the Charlton Model, the oxygen depletion rates for the BOC hypolimnion thickness was compared to the oxygen depletion rate for a reduction of one foot in hypolimnion thicknesses. The calculations were restricted only to years for which recorded hypolimnion thicknesses were available. A potential hypolimnion temperature variance was investigated by applying a model developed by Sundaram et al. (1969), which predicts the date of the onset of thermal stratification. Inherent in this simulation was the assumption that the hypolimnion temperature at the onset of stratification, usually in June, was equivalent to lake temperature immediately prior to stratification. The potential temperature variance was examined since a temperature increase could lead to acceleration of microbiological metabolic rates, thereby causing oxygen to be consumed at even higher rates.

3.3.4 Evaluation of Regulation Plans

Lake St. Clair - Lake Erie Western Basin:

A stable hypolimnion does not develop in either Lake St. Clair or the Western Basin of Lake Erie. Due to the shallow nature of both water bodies, winds cause intensive mixing, making these waters isothermal. Re-aeration is substantial due to the wind turbulence, resulting in uniform dissolved oxygen concentrations throughout the water column.

Lake Erie Central Basin:

A stable hypolimnion usually forms in the Central Basin of Lake Erie in June. During its existence the hypolimnion loses oxygen. The oxygen losses may be severe, tending to complete anoxia in some areas because the hypolimnion does not mix sufficiently with the overlaying oxygen bearing waters, and the bottom sediments contain oxydizable organic matter.

TABLE F-3

Lake Erie Anoxic Area (IJC, 1978b)

Year	Area (km^2)	June Mean Level (feet)
1930	300	571.83
1959	3600	570.50
1960	1600	571.24
1961	3640	571.31
1964	5870	569.64
1970	6600	571.54
1972	7970	572.27
1973	11270	573.49
1974	10250	573.22
1975	400	572.74
1976	7300	572.80
1977	2870	571.67

TABLE F-4

Depth-Volume Relationship For Lake Erie

Depth of Water* (ft.)	Volume of Water ($ft.^3$)
0.0	1.68×10^{13}
10.0	1.40×10^{13}
20.0	1.14×10^{13}
30.0	8.92×10^{12}
40.0	6.76×10^{12}
50.0	4.84×10^{12}
60.0	3.26×10^{12}
70.0	2.14×10^{12}
80.0	1.53×10^{12}
90.0	1.22×10^{12}
100.0	9.55×10^{11}
110.0	7.39×10^{11}
120.0	5.64×10^{11}
130.0	4.16×10^{11}
140.0	2.92×10^{11}
150.0	1.99×10^{11}
160.0	1.33×10^{11}
170.0	7.94×10^{10}
180.0	4.07×10^{10}
190.0	1.76×10^{10}
200.0	0.15×10^{10}
210.0	0.0

* Maximum depth of Lake Erie at Low Water Datum is 210 feet.

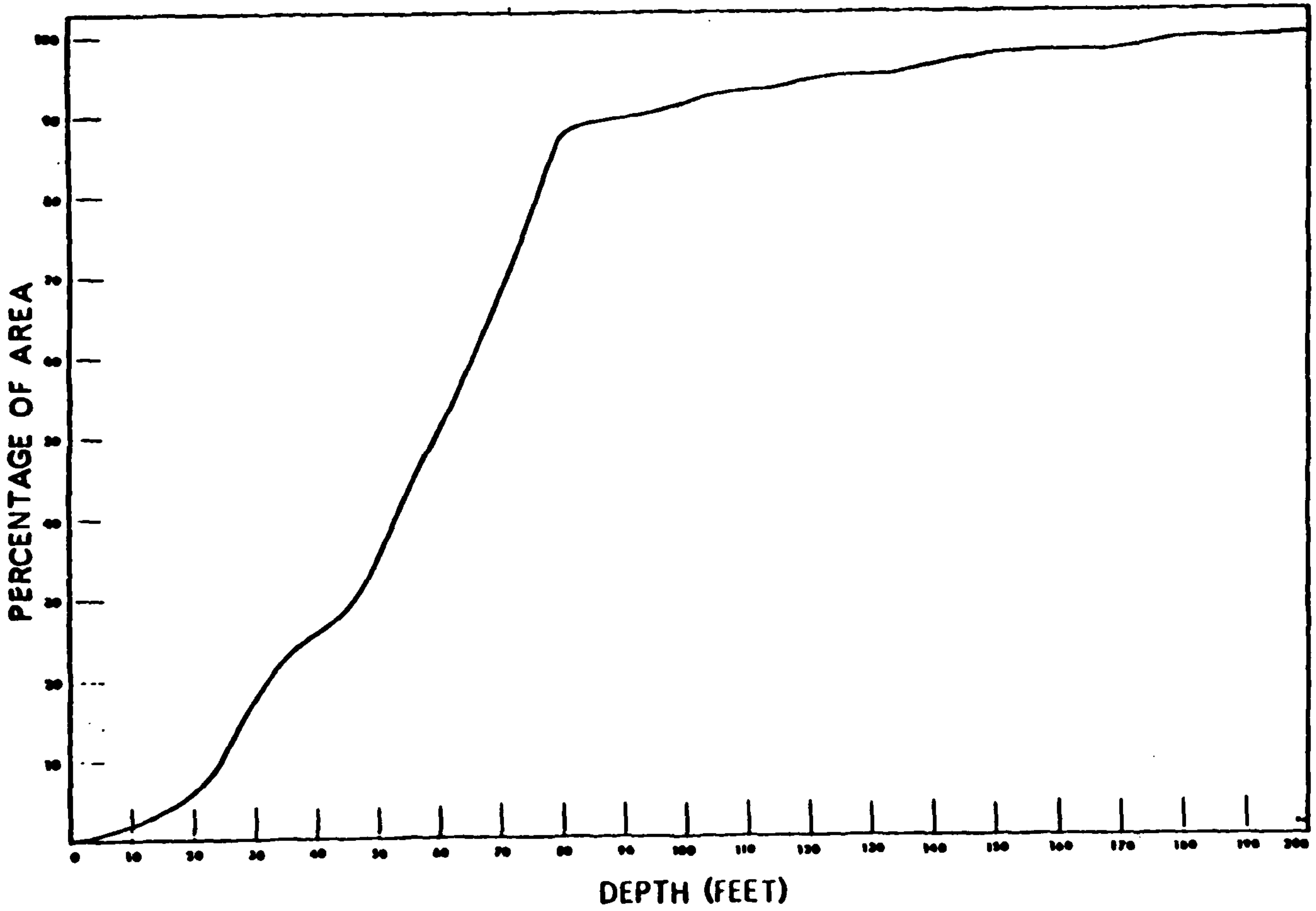

Figure F-1 **Depth-Area curve for Lake Erie.**

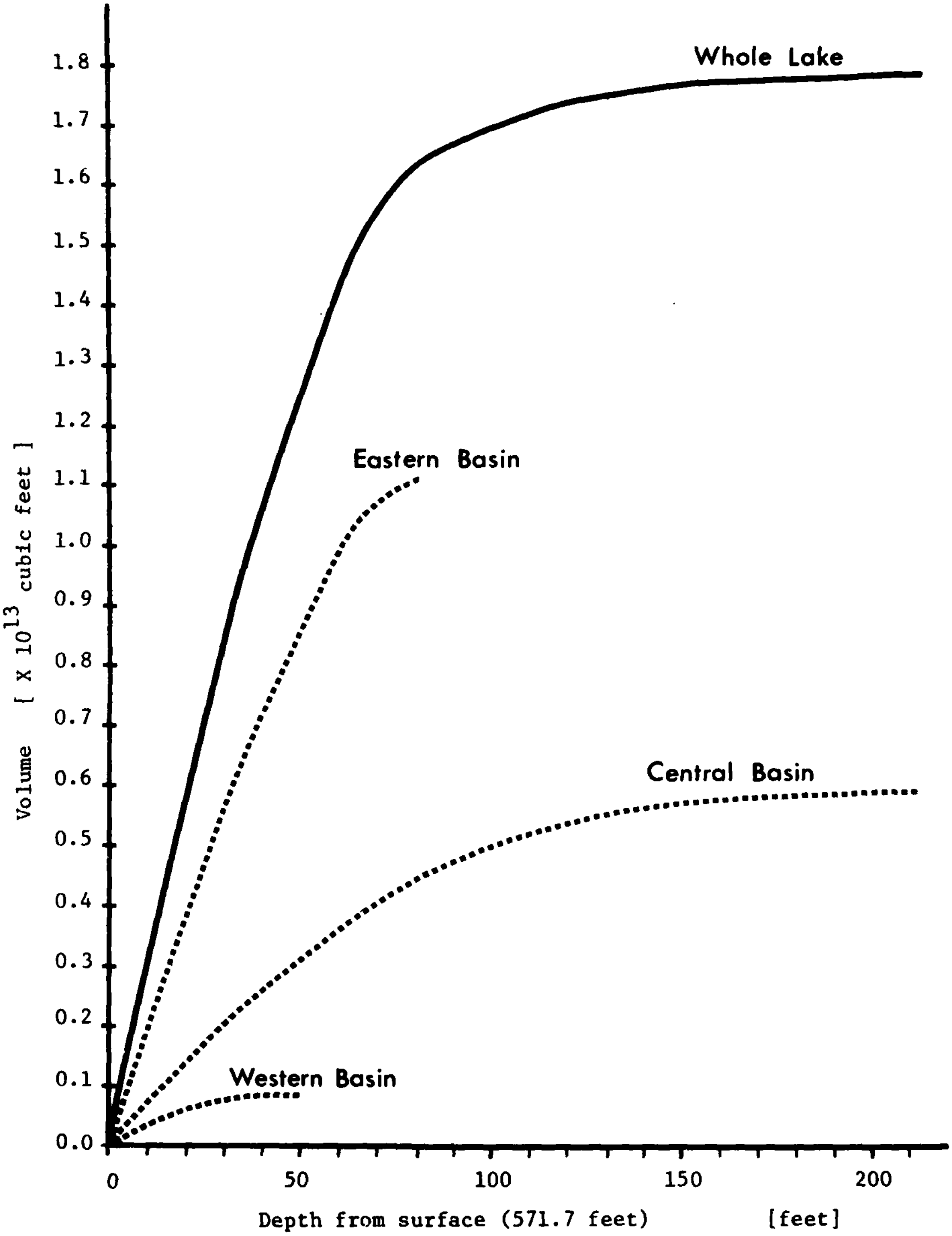

Figure F-2 Lake Erie volume versus depth

Table F-5 shows the 1970 hypolimnia volume for the Eastern and Central Basins of Lake Erie recorded during "Project Hypo" (Burns and Ross 1972). The 1970 hypolimnia thicknesses were reduced by one foot and the associated hypolimnia volumes were calculated and are tabulated. The largest predicted hypolimnion volume loss would be 15 percent (i.e., 3.6×10^{10} cu. ft. of water) for the August to September period.

Comparison of the BOC and Plan 25N mean Lake Erie water levels for May through September indicates a 0.6 foot decrease due to the plan. The decrease for the same period due to Plan 15S and Plan 6L would be approximately 0.2 and 0.1 foot respectively. The episodic hypolimnia volume reductions shown on Table F-5 are greater than the reductions that would occur under Plan 25N.

Employing the Charlton Model (1979), the change in the Central Basin hypolimnion oxygen depletion rate due to a one foot lowering of Lake Erie levels was investigated. Data were available only for the years 1960 to 1963 and 1967 to 1970. The hypolimnion dissolved oxygen concentration curves as plotted by Charlton for the above mentioned eight years were adjusted to account for a one foot lowering in the level of Lake Erie. From these adjustments it appears that there would be little change in the dissolved oxygen concentration at the end of August, when anoxic conditions would usually be present. Fig. F-3 illustrates the above procedure for 1970 data. The 95 percent confidence interval for the predicted oxygen concentration and the error interval which would result by miscalculating the hypolimnion thickness by 0.1 metre is also shown.

According to the Charlton model, no statistically significant change in the oxygen depletion rate (mg/L/mo) would be caused by a one foot reduction in lake level. Although total hypolimnion volume and the total oxygen reserves could be reduced by as much as 15 percent (1970 conditions), indications are that any potential anoxia would not occur significantly sooner under any of the regulation plans, than under BOC conditions.

By use of the model of thermocline formation developed by Sundaram et al. (1969), it was estimated that the onset of stratification would have been between May 14 and May 19 for 1978, a value consistent with field observations for that year. Using the Sundaram model, the onsets of thermal stratification were estimated for BOC (1978) and BOC (1978) minus 6 feet. These simulations indicate that lowering lake level up to 6 feet apparently would have little effect on the date of thermal stratification. Since actual water level changes experienced under any of the regulation plans would be well within the extremes of the simulation, regulation would not significantly alter the onset of stratification.

Assuming the temperature of the water in the hypolimnion is equal to the temperature of the overlying waters at the onset of stratification, and the onset is not affected by regulation, regulation would have no discernible effect upon hypolimnion temperatures, since stratification is initiated by temperature induced density differences.

TABLE F-5

Predicted Changes in 1970 Lake Erie Hypolimnia Volumes

SURVEY PERIOD	CENTRAL BASIN Measured "Project Hypo" (10^{10} ft.^{3})	CENTRAL BASIN Predicted 1-foot lower (10^{10} ft.^{3})	EASTERN BASIN Measured "Project Hypo" (10^{10} ft.^{3})	EASTERN BASIN Predicted 1-foot lower (10^{10} ft.^{3})
June	144.08	136.55 - 5.2%	191.41	176.41 - 7.8%
July	107.60	100.07 - 7.0%	122.37	115.85 -11.4%
August	114.23	106.71 - 6.6%	129.85	115.85 -12.0%
September	24.16	20.49 -15.2%	100.5	905. -10.0%

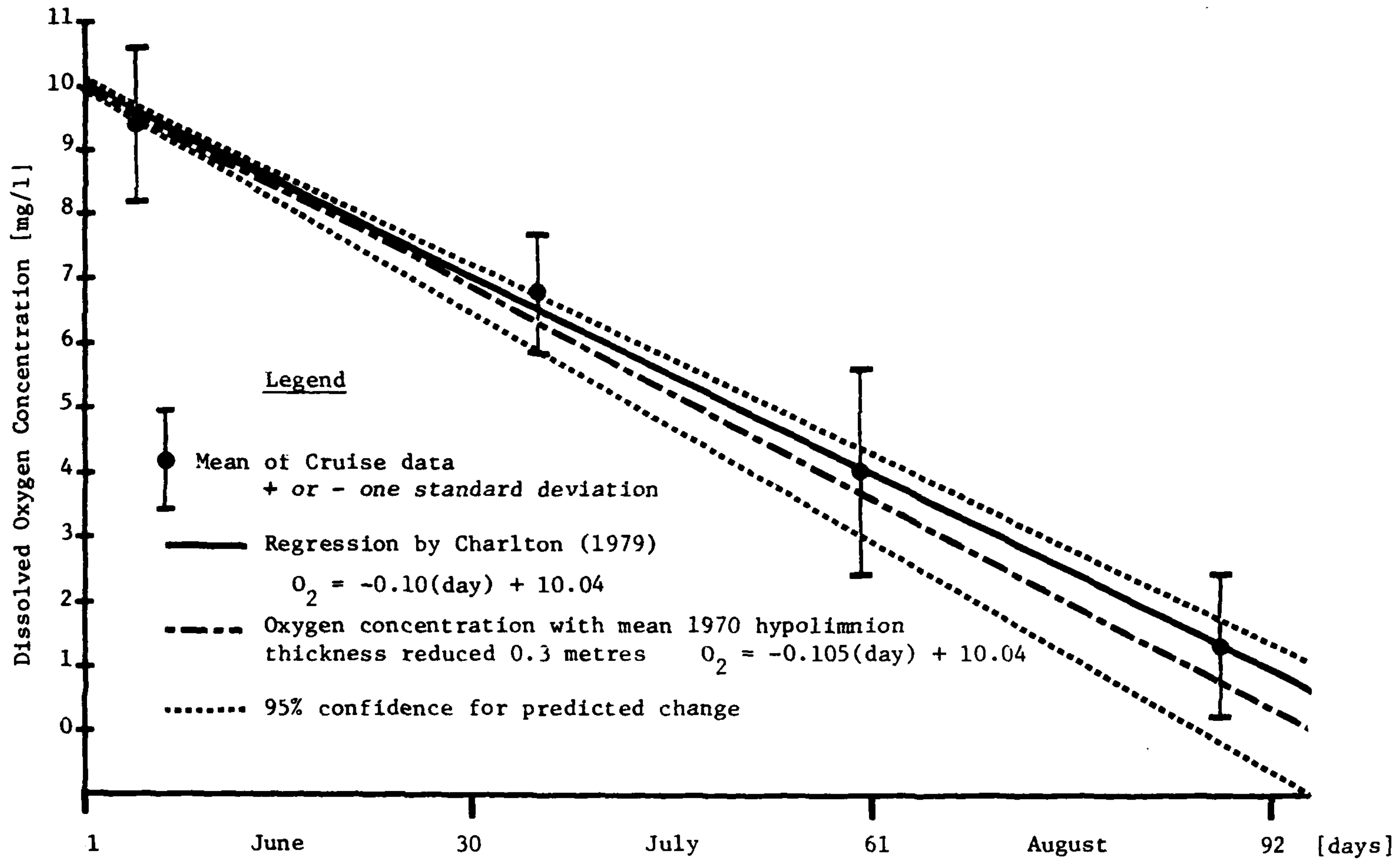

Figure F-3 Comparison of dissolved oxygen concentration in Central Basin in 1970, with mean monthly BOC level and a one foot decrease from that level.

Lake Erie-Eastern Basin:

Analysis similar to that conducted for the Central Basin were also done for the Eastern Basin. Results indicate that a one foot lowering of Lake Erie levels would result in a hypolimnion volume loss in August of up to 12 percent. The morphology of the Eastern Basin, however, along with the cleaner water therein, would result in a hypolimnion oxygen depletion rate that is approximately one-half of that for the Central Basin. Anoxia does not or is not likely to occur in the Eastern Basin. In fact, during 1970 when the mean volume weighted Central Basin hypolimnion oxygen concentration decreased, the mean volume weighted hypolimnion oxygen concentration in the Eastern Basin always exceeded 7.0 mg/L (Burns 1976).

Lake Ontario:

The hypolimnion volume of Lake Ontario is substantially greater than that of Lake Erie. Dissolved oxygen concentrations in the hypolimnion have been observed to remain relatively high during the period of thermal stratification (Environment Canada 1973). It is anticipated that the slight changes in water level due to regulation would not cause any appreciable changes.

3.4 Turbidity

3.4.1 Existing Conditions

Lake Erie nearshore turbidity has been observed to vary dramatically, not only between geographical area (OME 1972), but also from day-to-day. In general, shoreline areas experience consistently higher levels of turbidity than the open lake. The areas of higher turbidity include the Port Stanley area on the Canadian shore, and Ohio area on the U.S. shore. These reaches are among the most erodible shorelines of the Great Lakes.

Higher turbidity values generally occur in spring and fall, and can largely be attributed to the effects of storms which are usually most prevalent during these periods. Other factors such as algae blooms, lake turnover or dredging activities can contribute to increased turbidity levels. Nearshore turbidity generally originates from three main sources:

1. resuspension of lake bottom sediments by water movements such as waves and currents;

2. sediments from shoreline erosion caused by waves; and

3. suspended solids from tributary streams.

These sources contribute to the turbidity in the nearshore zone. While it is impossible to quantitatively relate inlake turbidity to any of the three sources listed above, it is possible to determine the relative contribution of turbidity causing materials from the latter two. Table F-6 shows the estimates for these contributions for Lakes Erie and Ontario.

3.4.2 Implications of Water Level Fluctuations

In addition to being aesthetically displeasing, turbidity contributes to the cost of water treatment. Costs relate to the amount of treatment chemicals used, to the larger amounts of backwash water needed due to shortened filter runs, and in some cases to the treatment of larger amounts of filter and sediment tank wastes prior to discharge. Moreover, through dispersion, turbidity can affect light penetration thus impacting upon Cladophora production and other plant life in susceptible areas. Regulation could reduce turbidity by reducing shoreline erosion, a major contributing source to lower lakes turbidity.

The ongoing process of resuspension of bottom sediments could be affected by regulation of lake levels. As levels are modified wave actions and water movements could shift to different areas of the nearshore lake bottom. This would alter sediment suspension regimes and possibly cause adverse effects at the site of nearshore water intakes.

Erosion is a major contributing source of turbidity in the nearshore waters along the highly erodible shoreline of the lower Great Lakes. The major cause of erosion, and consequently erosion damage, is wave energy attacking the toe-of-the-bluff. To evaluate erosion damages (See Coastal Zone Appendix), it was assumed that wave energy, and shoreline damages were directly related; i.e., the greater the wave energy, the greater the shoreline damages. Regulation would reduce wave energy reaching the toe-of-the-bluff and would thereby reduce both erosion and erosion damages. Table F-7 lists the estimated change in shoreline properties damage due to regulation. By extension, through the linear relation assumption, the estimated damage change is an indicator of the change in quantities of material eroded.

3.4.3 Methodology

The extent of wave-induced resuspension of sediments in nearshore waters, has been investigated as a function of wave height, wave period, and entrainment rate of bottom sediments (Chester and Delfino 1978). Unfortunately, the technique could not be readily adapted to predict regulation induced changes in nearshore turbidity, and consequently was not employed.

The potential reduction in turbidity due to regulation was examined through a multiple regression model that included turbidity expressed in Jackson Turbidity Units (JTU), toe-of-bluff wave energy, lake level and seasonal effects, in various combinations. Monthly toe-of-bluff wave energy data were available for various 10-year periods, having been calculated by the Coastal Zone Subcommittee from a hindcast wave model (see Appendix C - Coastal Zone)

Comprehensive regressions were confined to four reaches: Ohio State Data (Reaches 3002 and 3003); Grimsby on Lake Ontario (Reach 2002); and Elgin Area Water System on Lake Erie (Reach 3009).

Table F-6

Loadings of Suspended Solids and Sediments from
Shoreline Erosion to Lakes Erie and Ontario (PLUARG 1978)
(metric tons/yr)

Lake	Tributary (suspended solids)	Shoreline Erosion (total sediments)	Total
Erie	6,531,800	11,131,000	17,662,800
Ontario	1,597,000	3,206,000	4,803,000

Table F-7

Change in Erosion Damage Due to Regulation Plans

(Total Annual U.S. and Canadian Average)

	% Change 6L	% Change 15S	% Change 25N
Lake Erie	+3.1	+8.4	+17.8
Lake Ontario	+0.1	-1.2	-1.4

+ indicates reduction in erosion

- indicates increase in erosion

A statistical analysis of the Ohio data results in the following predictive model:

$$567.9 + 0.0020 \underset{[\text{million ft-lb/ft of beach}]}{(\text{toe-of-bluff wave energy})} + 2.10\,(\text{month}) - 0.983 \underset{[\text{ft}]}{(\text{lake level})} = \underset{[\text{JTU}]}{\text{turbidity}}.$$

The month of January is set at 1 whereas the month of December is equalled to 12.

The correlation coefficient of the Ohio model was approximately 0.20, that is, twenty percent of the turbidity variance resulting from wave energy, season and lake level can be explained by the model. In the analysis of variance, it was determined that of these three factors, lake level proved least significant as shown by the high standard error of the coefficient. The relative insignificance of the lake level contribution to the Ohio reaches analysis can most likely be explained by the enormity of the anthropogenic sources of turbidity in the study area.

The following model represents the results of the analysis of the Grimsby data:

7.3 + 0.0006120 (toe-of-the bluff wave energy) = Turbidity.

The correlation coefficient of the Grimsby data is 0.36. It is evident that the Grimsby model can explain almost twice as much of the turbidity variance when compared to the Ohio model. Most likely this is due to the paucity of anthropogenic sources in this area relative to the Ohio reaches.

The Elgin data did not produce statistically significant results until a seasonality factor was introduced into the regression analysis. The following models, which are significant at the 95 percent confidence level, result:

March & April

26.4 + 0.00205 (toe-to-bluff wave energy) = Turbidity

May & June

12.3 + 0.000829 (toe-of-bluff wave energy) = Turbidity

July & August

8.0 + 0.00307 (toe-of-bluff wave energy) = Turbidity

November

31.5 + 0.00179 (toe-of-bluff wave energy) = Turbidity

The regression analysis of December, January, and February data were inconclusive, most likely due to the ice conditions which armoured the shoreline thereby reducing erosion. September and October correlations were

not significant, possibly due to the breakdown of stratification during this period.

Through a variance analyses, it was determined that a strong relationship between wave energy at toe-of-bluff and turbidity exists. Location and season of the year also have a strong influence on turbidity. Lake levels influence turbidity only indirectly by affecting toe-of-bluff wave energy. The regression models were developed to define the erosional sources of turbidity, since only these sources would be affected by wave energy. However, when relating actual nearshore turbidities to the pertinent models for calibration and prediction purposes, it became obvious that much of the nearshore turbidity could not be explained by erosion. Other factors including anthropogenic sources, and inlake biological and chemical processes appear to be equally important.

Fig. F-4 illustrates the variation of turbidity versus lake level for Lake Erie assuming March 1970 conditions. In order to fully evaluate the impact of the various regulation plans it would be necessary to produce graphs similar to this figure for every month over the 77 year period of evaluation. However, for the reaches examined, the period of evaluation was restricted to the period over which wave energy data were available. In this study the 1967-1976 period was considered in all instances. The impact of regulation was determined on a monthly basis by relating turbidity to BOC and regulation plan water levels. This procedure was repeated for the relevant months over the period of evaluation and a mean change in turbidity determined.

The above procedure was programmed to provide reproduction of graphs similar to Fig. F-4. Annex I provides a listing of the program and an example evaluation.

3.4.4 Evaluation of Regulation Plans

The change in nearshore turbidity was predicted for the three regulation plans by using the model developed from the Elgin Area regression analysis. The results appear in Table F-8.

The largest mean reduction in turbidity over the period of evaluation would be 2.5 JTU (11 percent) under Plan 25N. Plans 6L and 15S would produce mean turbidity reductions of less than five percent.

It should be noted that any lake level induced reductions in turbidity would be confined to areas with highly erodible shores. The relationships developed between wave energy and turbidity are not transferable from reach to reach. However, similar relationships are anticipated for other susceptible reaches.

Fig. F-4 was developed using March 1970 wave energy conditions and employing the models previously described. It gives crude estimates of turbidities at the Port Stanley, Port Clinton, and Madison nearshores based upon toe-of-bluff wave energies as affected by lake levels. The Port Clinton and Madison analyses indicate dramatic increases in turbidity at Lake Erie levels above 570 ft. The highest Lake Erie still water monthly mean level

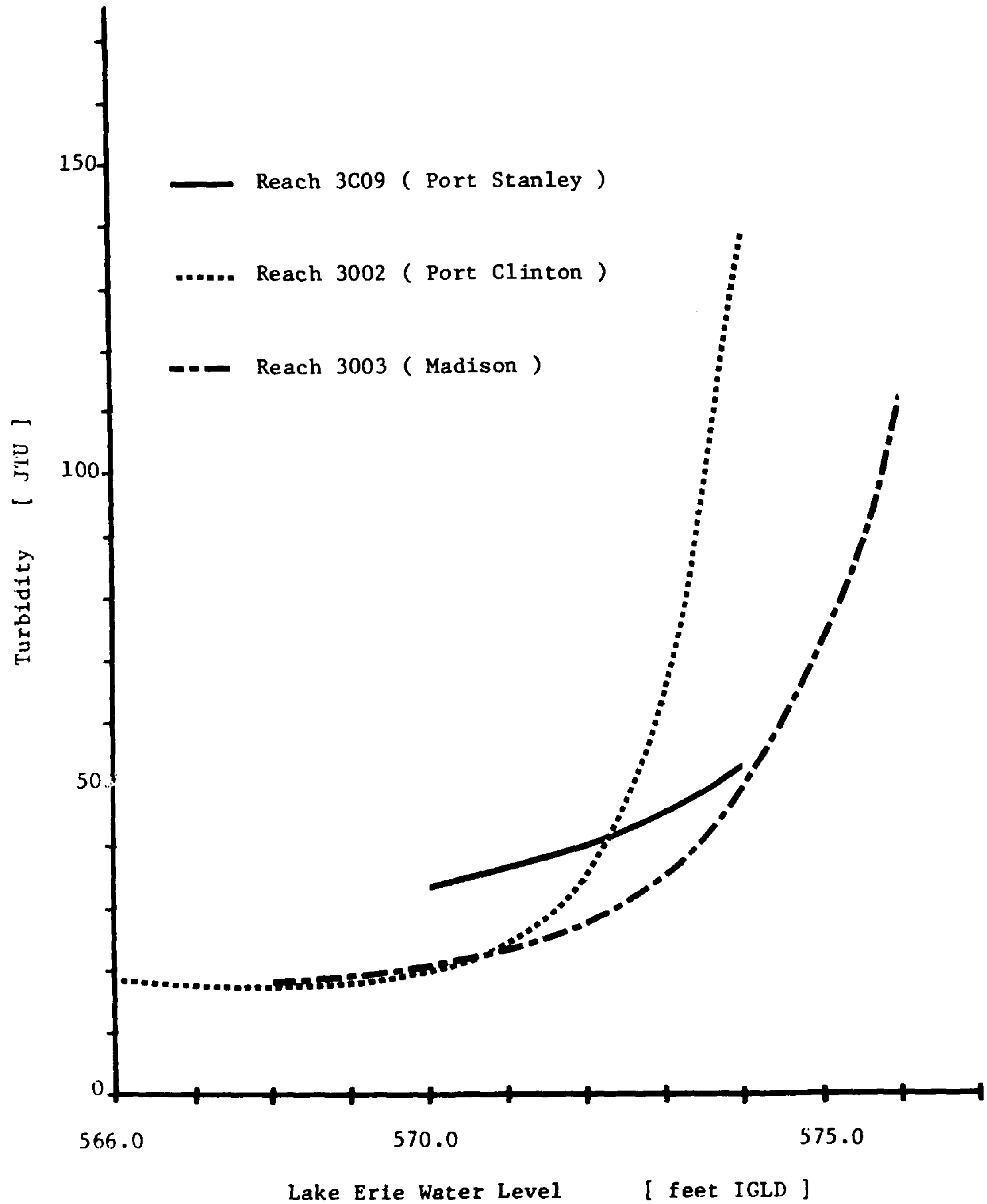

Figure F-4 Variation of turbidity with lake level assuming March 1970 wave energy conditions

Table F-8

Effects of Plans on Raw Water Turbidity
at Elgin Area Water Treatment Plant

(1967 - 1976[1])

	BOC	6L	15S	25N
Mean Turbidity (JTU)	22.3	21.8	21.2	19.8
Mean Turbidity Change		-0.5	-1.1	-2.5
Percentage Change	-	-2.2	-4.9	-11.0

1 Months of January, February, September, October, and December are not included in calculations.

Table F-9

Effects of Category 2 Plans on Raw Water Turbidity
at the Grimsby Water Treatment Plant

(1967-1971[1])

	BOC	6L	15S	25N
Mean Turbidity (JTU)	14.3	14.5	14.6	14.5
Percentage Change	-	+0.2	+0.3	+0.3

Table F-10

Effects of Category 3 Plans on Raw Water Turbidity
at the Grimsby Water Treatment Plant

(1967-1976[1])

	BOC	6L	15S	25N
Mean Turbidity (JTU)	14.3	14.0	14.1	14.0
Mean Percentage Change	-	-.3	-.2	-.2

1 Months of December, January and February are excluded due to ice conditions.

ever recorded was 573.5 ft. in 1973. Short term higher levels due to wind and barometric effects have been recorded and the dramatic increases alluded to above may only be experienced during these meteorological extremes. Should extrapolation of the turbidity and wave-energy models be realistic, it can be anticipated that Plan 25N could produce significant decreases in turbidities during extreme meteorological events.

The changes in nearshore turbidty on Lake Ontario are minimal and would likely not be perceivable (Table F-9). The Category 2 regulation plans would maintain the long-term mean level of Lake Ontario within 0.1 foot of the long-term mean BOC level.

As is the case with Categoty 2, Category 3 plans would not cause any significant change in turbidity. Category 3 results for Grimsby are shown in Table F-10.

3.5 Embayments

3.5.1 Existing Conditions

Along the Canadian and U.S. shorelines of the lower Great Lakes there are a large number of embayments, many of which have social and/or ecological significance. Embayments such as Toronto, Hamilton, Lorain, and Mentor Harbors are focal points of intensive human activity. They serve a variety of uses such as water supply, navigation, recreation, and waste disposal. Other embayments, because of conducive physical characteristics, are important wetland ecosystems. These wetlands serve as staging areas and habitats for various birds and mammals, as well as spawning grounds and feeding areas for fish.

Unfortunately, embayments frequently experience poor water quality. Regulation could compound existing water quality problems. The degree to which water quality in an embayment may be affected by lake level regulation depends upon the physical characteristics of the embayment. Important physical characteristics for classification of embayments are size, configuration, depth, degree of closure, and associated tributary streams.

Current U.S. National Ocean Surveys hydrographic charts were used to examine the U.S. coast of Lake Erie. Forty-two embayments were identified and classified as either: 1) embayments dominated by tributary input; 2) embayments with relatively large lake-bay interface (unrestricted) or 3) embayments with a relatively small lake-bay interface (restricted). These classifications were based solely on visual inspection of the charts. Most of the embayments examined (26 of 42) were judged to be hydrologically dominated by tributary inputs. Of the remaining embayments, eight were judged to have relatively large lake-bay interfaces (unrestricted) and the other eight were considered restricted hydrologically (small lake-bay interface) to some degree.

A similar examination of the U.S. coast of Lake Ontario revealed that of 39 embayments identified, 17 appear to be dominated by tributary inputs; 14 of the remaining are relatively unrestricted hydrologically, while the other 8 are restricted to some degree.

On the Canadian side, in addition to hydrographic charts, topographic maps and aerial photographs were examined. On Lake Erie, 19 embayments were judged to fit into the tributary dominated category. Twenty-four of the remaining embayments have a large lake-bay interface (unrestricted) while the remaining five are restricted. On Lake Ontario, 35 and 29 embayments were judged to be tributary dominated and unrestricted respectively. Thirty-one embayments were considered hydrologically restricted to some degree. The vast proportion of these embayments are located in the Prince Edward County of Eastern Lake Ontario.

3.5.2 Implications of Water Level Fluctuations

The water quality within an embayment can, in part, be influenced by two mechanisms which are directly affected by the regulation plans:

1. long-term lowering of lake levels could change the conveyance capacity of restrictive outlet channels, thereby altering water exchange between embayment and lake; and
2. the dilution capacity - i.e., lower lake levels will reduce the volume of water available within the embayments for dilution.

Should the embayment dilution afforded by lake water intrusion be reduced water quality inside the embayment could suffer. As a worst case, the dilution capacity loss could aggravate the toxic potential of a slug pollutant load. This could adversely affect, if not completely destroy, the existing biologic communities inhabiting the embayment.

3.5.3 Methodology

The water quality of embayments is affected by the volume of the embayment and the quantity of embayment water exchanged with the lake. The exchange process is driven by short-term meteorological fluctuations in lake level. Lake Erie regulation would not alter the short-term fluctuations which drive the exchange of waters between lake and bay but would alter the long-term levels which affect the magnitude of the exchange.

Changes in wave motion, coastal currents, tributary currents, and wind driven currents due to regulation could not be anticipated. Consequently, their effects on water quality within the embayment were not considerated.

Water Exchange

A model adapted by Dick and Marsalek (1973) to simulate the exchange of flow between Lake Ontario and Hamilton Harbor was employed for this study. The model considers channel depth, length, width, channel wall friction, embayment surface area, and the inflow of water from tributary sources as factors influencing the degree of water exchange. As such, the level fluctuations inside an embayment may not necessarily equal or coincide with lake wide level changes. In this event the connecting channel between lake and embayment is "choking" or reducing the exchange of water. Annex 2 contains the computer program used in this study.

The regulation induced impacts of potential alterations in water exchange were examined by evaluation of a choking coefficient as defined by Dick and Marsalek (1973). From hydrographic charts, the connecting channel characteristics and embayment surface areas were measured for various embayments on Lakes Erie and Ontario. The "choking coefficients" were calculated to evaluate the sensitivity of the coefficient to lake level decreases. For these calculations it was assumed that all factors affecting lake-bay interface, except channel depth, would remain constant under lake level regulation. Of the embayments examined, only Hamilton Harbor experienced "choking" and this is attributed to its large surface area and not to channel depth.

From the analysis of the "choking coefficient", it was concluded that lower lake levels, and consequently shallower connecting channels, would not cause an appreciable difference in the quantity of water exchanged due to a disparate water level between lake and embayment.

The water quality of an embayment is continuously changing due to variations in sewer outfall discharge, sediment deposition, sediment resuspension, stream inputs, local runoff and other factors. In view of the dynamic nature of embayment water quality and limited baseline information defining the stresses which affect local water quality, attention was focused on percentage changes in pollutant concentrations, rather than absolute pollutant concentrations.

If a single event is considered where a wind set-up causes lake water to enter an embayment, the resultant embayment pollutant concentration is presented by the following equation:

$$C_1 = Co + (S+F(D-\Delta d))/(D-\Delta d +S)$$

where C_1 is the post set-up embayment pollutant concentration in mg/l; Co is the lake pollutant concentration, F post set-up embayment pollutant concentration divided by the lake pollutant concentration ; S is the embayment level increase in feet due to the set up; D is the BOC embayment water depth in feet without the seiche; and Δd (BOC minus Plan) is the change in lake level (in feet) due to regulation.

For the BOC case C_1 was calculated assuming a Δd value of 0.0 feet. For the plan being evaluated, C_1 is recalculated using a Δd value which represents a difference in water level between BOC and the regulation plan. The C_1 values are compared to determine the percentage pollution difference (see Table F-11 for an example). Note that for embayments with depths in excess of 18 feet, the effects on pollutant concentration are minimal.

The model is applicable for cases when the lake water quality is either superior or inferior to embayment water quality. For the purpose of this study it was assumed that lake water quality is superior to embayment water quality. Accordingly, water entering an embayment from the lake dilutes and therefore reduces embayment pollutant concentration.

Table F-11

An Example[1] of the Effect of Water Exchange on Embayment Pollutant Concentrations due to Wind Set-Up under Regulation

BOC Embayment Mean Water Depth (feet)	Percent Decrease Over BOC Concentration due to Indicated Mean Water Level Decrease (d)		
	6L d=0.09 ft.	15S d=0.23 ft.	25N d=0.59 ft.
3	0.3	0.9	2.5
6	0.1	0.3	0.7
12	0.0	0.1	0.2
18	0.0	0.0	0.0

1 The above simulation assumes the following conditions.
$F = 2.0$
$S = 1.0$ foot
$C_o = 20$ mg/1
D = as indicated

Table F-12

An Example of the Concentration Increase Due to Reduced Dilution Under Instantaneous Loading

BOC Embayment Mean Water Depth (feet)	Percent Increase Over BOC Concentration[2] due to Indicated Mean Water Level Decrease (d)		
	6L d=0.09 ft.	15S d=0.23 ft.	25N d=0.59 ft.
3	3.1	8.3	24.5
6	1.3	3.8	10.9
9	1.0	2.6	7.0
12	0.8	2.0	5.2
18	0.5	1.3	3.4

2 The above simulation assumes banks in the embayment and as initial pollutant concentration of $C^* = 0.0$ mg/1.

Set up activity can also lower lake levels at the outlet of an embayment generating an outflow from the embayment. The quality of the water exiting the embayment was assumed to equal the concentrations initally within the embayment. For simulation purposes it was assumed that the pollutant is instantaneously dissipated within the lake.

Embayment Dilution Capacity:

Changes in embayment volume affect the quantity of water available for dilution. The embayment concentration of a pollutant can be represented approximately by the following equation:

$$C_{new} = C^* + \frac{M}{(D-d)\,A}$$

where C_{new} is the post-regulation pollutant concentration (assumed to have zero volume); C^* is the pre-regulation pollutant concentration within the embayment; M is the mass of the pollutant; D is the BOC depth in the embayment; A is the area of the embayment; and d (BOC minus Plan) is the water level change due to regulation. Since M and A would remain constant under BOC or a regulation plan, the change in concentration is inversely proportional to the change in depth assuming an embayment with vertical sides (i.e., no littoral zone).

Table F-12 shows an example of the percentage increases in pollutant concentration due to dilution capacity loss for various embayment depths and plans. The table indicates that reduced embayment volume due to regulation would increase embayment pollutant concentration which would be critical especially in the case of a slug pollutant load (e.g., accidental spill, by pass due to equipment malfunction, etc.).

3.5.4 Evaluation of Regulation Plans

Embayments on Lakes Erie and Ontario were selected to illustrate the mechanics of various embayment characteristics. The following five cases were studied intensely since they provide variations of the principal classification types.

	Embayment	Characteristic Features
Lake Erie	Mentor Harbor	Shallow embayment with possible restricted outflow channel
	Dunkirk	Embayment with medium depth and unrestricted outflow channel
	Lorain Harbor	Embayment strongly influenced by tributary flows
	Sturgeon Creek	Shallow embayment with possible restricted outflow channel
Lake Ontario	Ham. Harbor	Large, deep embayment with possible restricted outflow channel

Lower water levels which would be experienced on Lake Erie under all plans enhance the mechanism of the water exchange between an embayment and the open lake in direct proportion to the degree of lowering. The benefits that would be attributed to embayment flushing could at times be offset by the increased pollutant concentrations resulting from dilution capacity loss. As an example, a pre-regulation pollutant concentration in Mentor Harbor would increase by a 20% maximum with a water level lowering of one foot, Embayment flushing would slowly dilute the increased embayment pollutant concentration, but the time required to revert to initial concentrations would be extended. In the case of Mentor Harbor, the pollutant concentration after 72 hours would still be six percent above that of the BOC condition. Using deeper Little Sodus Bay as an example, it was determined that the response would be similar but not as dramatic due to the deeper water in the Bay.

Evaluation of embayments more shallower than Mentor Harbor (6 feet) was not attempted. Extremely shallow embayments respond more like marsh ecosystems. While the assimulative capacity of a marsh can be very high (at times it can also act as a source), the effects of regulation could not be predicted.

In summary, for embayments that are influenced by tributary input, lake regulation would result in indiscernible changes in water quality since this type of embayment would be predominantly influenced by tributary water quality. In embayments with unrestricted connection to the lake, only minimal effects in the lake-embayment water exchange process would be experienced under any plan. A dilution capacity loss would occur on Lake Erie, but with the rapid response of this type of embayment to set up action, the effect of the water exchange process would be enhanced. In embayments on Lake Erie with a restricted connection to the Lake, the dilution capacity loss would produce adverse water quality effects that would more than offset the benefits of increased water exchange. The maximum detrimental effects would be experienced under Plan 25N with proportionally less effects due to the other two plans. On Lake Ontario, little long-term embayment impact would be expected since relatively minor water level changes from BOC would occur.

Shallow embayments in Lake Erie with restricted mouths where dilution capability may be affected by regulation include: Sand Creek, Catawba West, Middle, and East Harbor, Sandusky Bay, Northeast Yacht Club, Mentor Harbor, Presque Isle Bay, Port Dover, and Sturgeon Creek. In Lake Ontario the regulation induced high lake levels would increase embayment water volumes thereby mitigating embayment pollutant concentrations.

3.6 Cladophora

3.6.1 Existing Conditions

The excessive growth of the alga Cladophora is a problem in the lower Great Lakes. As Cladophora increases, other rooted vegetation diminishes. The resultant Cladophora based community is characterized by

low species diversity and is unstable (Judd 1972). An economic effect of the decline in plant species diversity is the decline in the productivity of valuable fish species (Neil 1974); an effect that may be partially attributed to the seasonal deterioration of Cladophora and sedimentation of plant debris over shorelines and shoals. Christie (1973) indicates that the decaying sediments may create areas of localized deoxygenation in winter and affect the survival of whitefish and lake trout eggs.

Negative economic impacts also result when large masses of Cladophora detach from the substrate and become washed ashore or become suspended in floating mats. Malodorous, decomposing accumulations of the algae along shorelines have been claimed to reduce property values by 15 to 20 percent (Ormerod 1970). Neil (1974) obtained figures from provincial and state park agencies fronting Lake Ontario which indicate that between $2,000 to $12,000, spent in 1966 in beach-cleaning costs, can be attributed directly to Cladophora accumulations.

Although most industrial and municipal water intakes are generally located close to the bottom, outside of areas of Cladophora growth and accumulation, some power generating plants use surface intakes which are plagued by clogging of intake screens. Floating mats of Cladophora are also responsible for reduced fish catches due to the fouling of nets (Roland and Skoch 1975) and the decomposing alga is said to impart undesirable odors and tastes to drinking water (Neil and Owen 1964). Except for certain localities (e.g., the Bass Islands), the Central and Western Basins of Lake Erie are not seriously affected by Cladophora growth (Taft and Kishler 1973). The eastern portion of Lake Erie's Eastern Basin, especially the north shore, experiences luxuriant growths of Cladophora.

Extensive growths of Cladophora are experienced in Lake Ontario but are somewhat limited by the lower summer temperatures and nutrient concentrations than Lake Erie.

3.6.2 Implications of Water Level Fluctuations

Studies undertaken during the International Field Year on the Great Lakes (IFYGL) in 1972, indicate that Cladophora production is usually confined to the nearshore area. Depending on the bathymetry of the littoral zone of the particular lake and the shoreline topography, lake level fluctuations can alternatively increase or decrease the area available for Cladophora production.

During the major growing season, May - October, the duration and magnitude of high or low lake levels can adversely affect Cladophora growing at either hydrological extreme. Low levels over a few days to one week can lead to kills of algae clumps exposed to the air. Higher levels could decrease or increase availability of suitable substrate especially in areas with shallow slope and consequently affect production.

3.6.3 Methodology

The production of Cladophora depends upon various factors including nutrient concentration, light penetration, water temperature, currents, alkalinity, substrate availability, and predators. Of these factors, only light penetration and substrate availability would be considered affected by lake level regulation. Light availability as a controlling factor was not examined due to inadequate data. The results described below are based upon increased substrate alone. Annex 3 contains the computer program used in this study.

In determining the impact of lake level regulation the following assumptions were made:

1. nutrients are not limited in Lake Erie and Lake Ontario;
2. production is limited by availability of suitable substrate which is either bedrock or rubble/gravel;
3. the Cladophora production region is limited by the depth of light penetration, usually set at five metres; and
4. light penetration is independent of lake level.

Taft and Kishlet (1973) conducted an intensive study of Cladophora production in the Bass Islands Area of Lake Erie. Analysis of collected data indicates a variable yield with varying depth of water (See Table F-13). The production is most intense at a water depth of one metre, and diminishes with water depth from this point. The table indicates the resultant Cladophora production for the Bass Islands Area using the 1966 mean May BOC water level.

The technique employed to determine the Cladophora production for the Bass Islands region is illustrated in Fig. F-5. The substrate area available with respect to water depth is shows in column 1. The Cladophora yield (tons/acre/year) according to Taft and Kishler is plotted in column 2. Cladophora production for a specific water depth was calculated by multiplying columns 1 and 2 with the results in column 3. The total production for the reach is calculated by adding the results in column 3. By shifting the yield vs. depth curve the Cladophora production can be evaluated for various levels.

The resolution of the hydrographic charts are inadequate to estimate the available substrate area as a function of elevation for Lake Erie's Eastern Basin and Lake Ontario. An average annual yield of three tons/acre/year was estimated for the Eastern Basin (Miyamoto 1978). For the Canadian shoreline of Lake Ontario an average annual yield of two tons/acre/year was estimated (Miyamoto 1978). A Cladophora study conducted by Shear and Konasewich (1975) for Lake Ontario between Rochester and Stoney Point on the U.S. shoreline estimated a similar annual yield of 2.3 tons/acre/year.

3.6.4 Evaluation of Regulation Plans

Table F-13

Cladophora Production in the Bass Islands Region of the Western Basin of Lake Erie

Elevation (ft.)	Total Area Available for Growth at each 1' Elevation (Acres)	1966 BOC *Cladophora* Yield at 1' Elevation (ton/acre/year)	1966 BOC *Cladophora* production at 1' Elevation (tons/year)
575	122	-	-
574	51	-	-
573	33	-	-
572	45	-	-
571	75	-	-
570	129	1.09	140
569	227	1.31	297
568	371	3.09	1146
567	522	4.16	2172
566	580	3.96	2297
565	567	3.72	2109
564	465	3.66	1702
563	424	2.95	1251
562	394	2.40	946
561	373	1.67	623
560	357	1.25	446
559	344	0.44	151
558	332	0.35	116
557	228	0.17	39
556		0.09	-

TOTAL PRODUCTION (Tons/Yr) 13,435

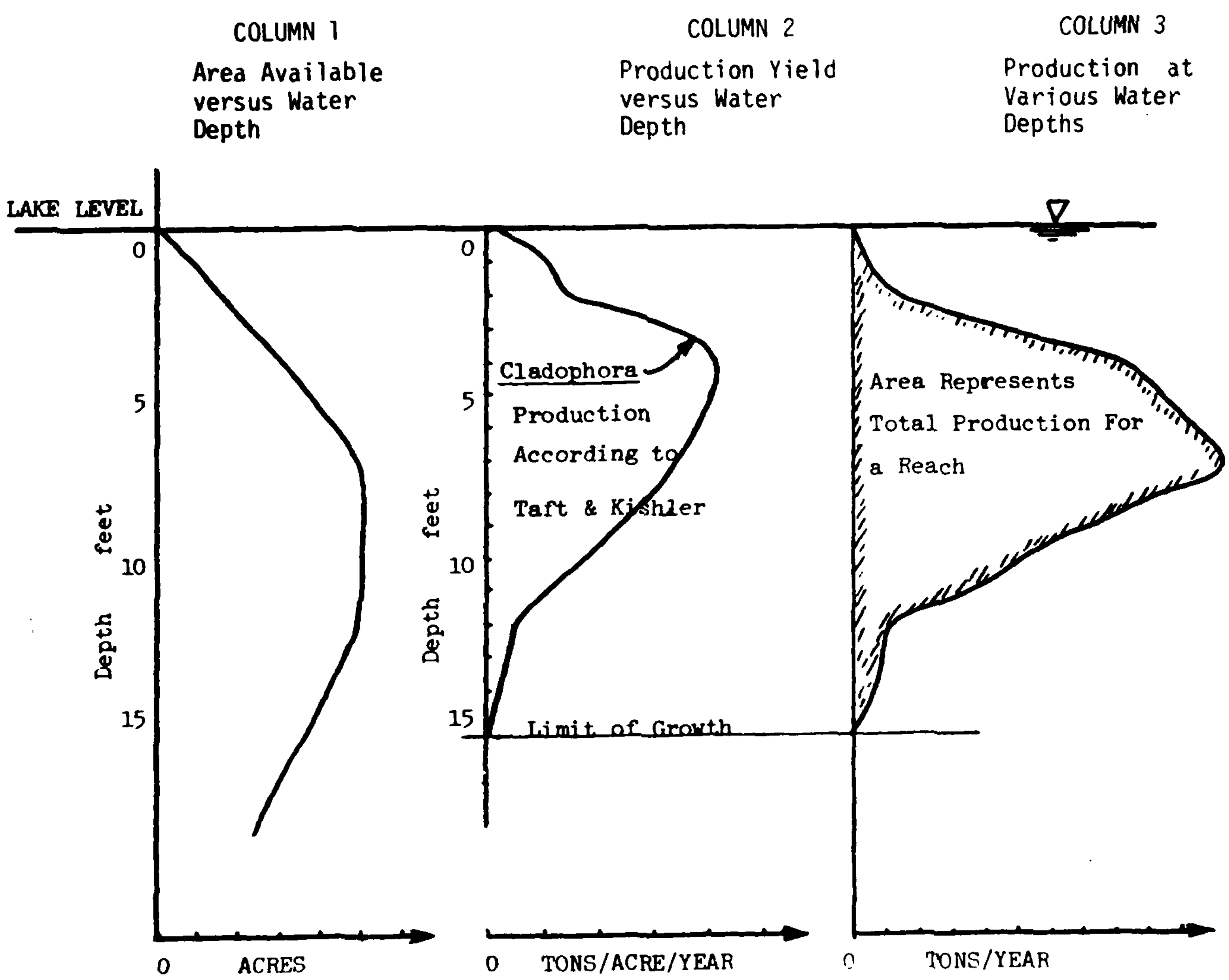

Figure F-5 Graphical Representation of Computer Technique Utilized to Calculate Total *Cladophora* Production for a Reach.

Lake St. Clair:

Due to the high fraction of clay in bottom materials and marshy shoreline (Upchurch 1975), Lake St. Clair does not experience appreciable Cladophora production. For this reason further analysis was not conducted.

Lake Erie:

Employing the yield to water depth relationship developed by Taft and Kishler (1973), the Cladophora production for the Bass Islands region under the regulation plans was estimated. Table F-14 summarizes the Cladophora production and the percent deviation from BOC for this region and the Eastern Basin of Lake Erie. Figs. F-6 to F-8 shows the annual production for the Bass Islands region for the three evaluated plans.

Fig. F-9 to F-11 shows the annual production for the three plans in the Eastern Basin.

In Lake Erie the regulation plans (6L, 15S and 25N) would cause mean long-term annual increases of Cladophora production of approximately 0.3, 0.9 and 2.0 percent, respectively. Within individual years there would be decreases in production, but increases of up to 14 percent could be expected for some years in the Bass Islands Region should the assumptions previously listed remain valid. It is likely however that nutrients will limit Cladophora production in the future. In fact this is the very goal of the U.S.-Canada pollution control programs currently in progress. If nutrients become limiting, Cladophora production in the lower lakes would decrease.

Lake Ontario

A *yield of two tons/acre/year* was employed for analysis of Cladophora production on the Canadian shoreline (Miyamoto 1978). The long-term mean Cladophora production for Lake Ontario Category 2 and Category 3 plans are shown in Table F-15. Figs. F-12 to F-14 show the annual predicted production over the 77-year study period and the percentage change from BOC for Category 2 plans. Figs. F-15 to F-17 show the same parameters for Category 3 plans.

Under Category 2 plans the long-term mean annual Cladophora production in Lake Ontario would be decreased. Under Category 3 the long-term mean annual Cladophora production in Lake Ontario would be increased slightly for Plan 6L and would decrease for Plans 15S and 25N.

3.7 Waste Discharges

3.7.1 Existing Conditions

In general, municipal and industrial waste waters, after being given suitable treatment, are released to receiving waters via outfall systems. The waste water, being warmer than the ambient receiving water,

Table F-14

Long Term Mean Annual Cladophora Production (tons/year) for Lake Erie. (1900-1976)

PLAN	Bass Islands	Eastern Basin	Total
BOC	13012	9898	22910
6L	13081	9910	22991
15S	13194	9931	23125
25N	13362	10006	23368

Table F-15

Lake Ontario Long-Term Mean Annual Cladophora Production (tons/year) - North Shore - Wellington to Brighton

Plan	Category 2	Category 3
BOC	14271	14271
6L	14257	14279
15S	14226	14263
25N	14202	14194

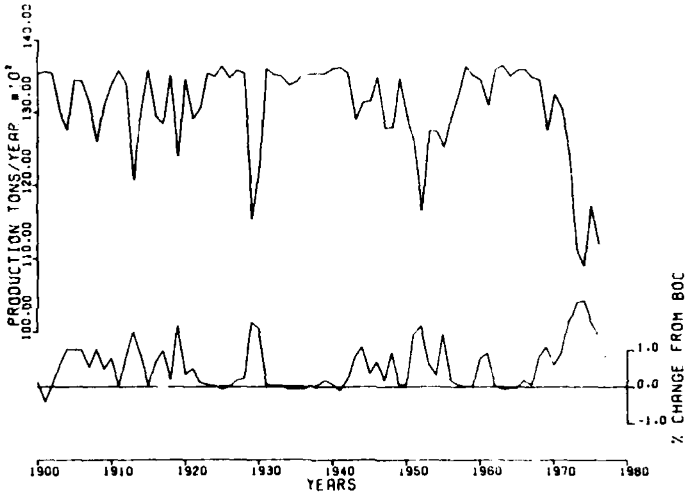

FIGURE F-6 :BASS ISLANDS CLADOPHORA PRODUCTION FOR PLAN 6L

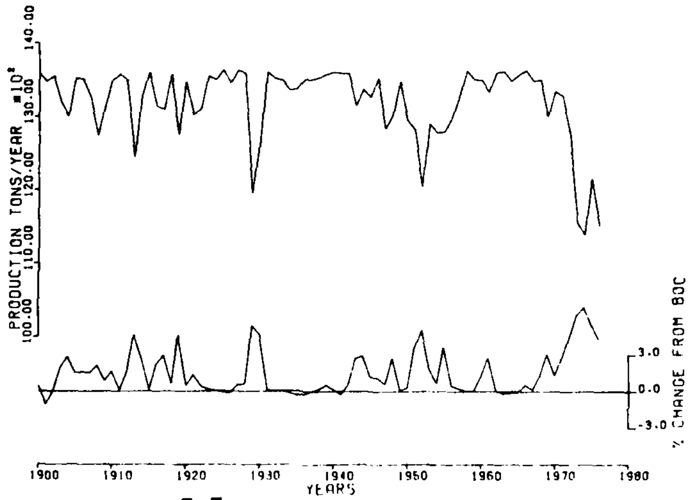

FIGURE F-7 :BASS ISLANDS CLADOPHORA PRODUCTION FOR PLAN 15S

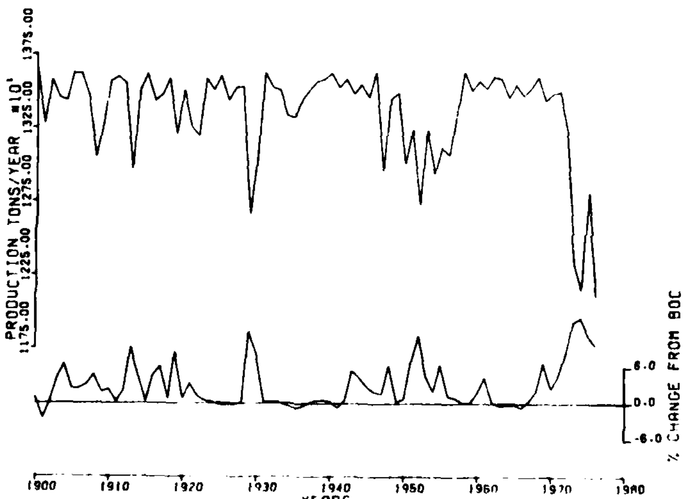

FIGURE F-8 :BASS ISLANDS CLADOPHORA PRODUCTION FOR PLAN 25N

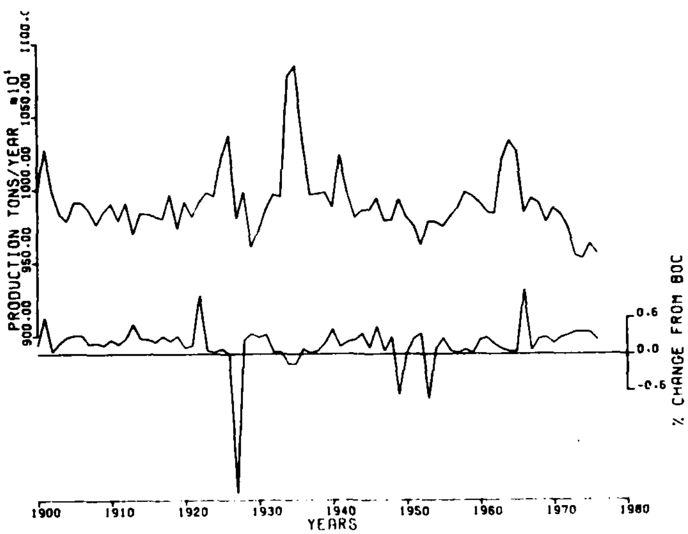

FIGURE F-9 :EASTERN BASIN CLADOPHORA PRODUCTION FOR PLAN 6L

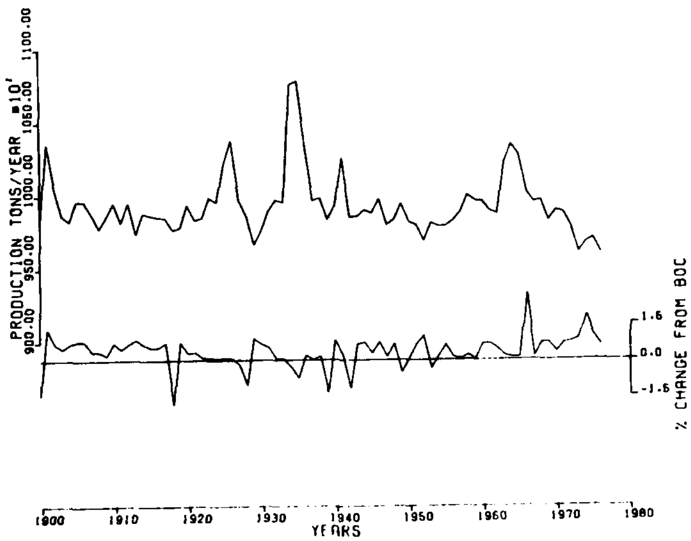

FIGURE F-10:EASTERN BASIN CLADOPHORA PRODUCTION FOR PLAN 15S

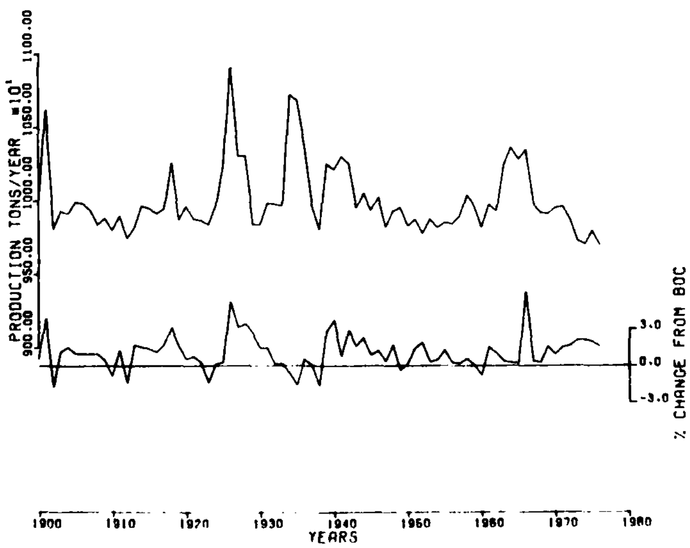

FIGURE F-11 :EASTERN BASIN CLADOPHORA PRODUCTION FOR PLAN 25N

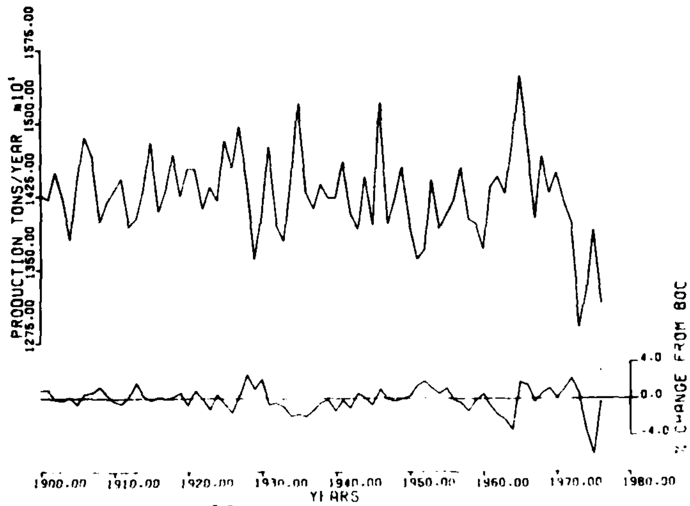

FIGURE F-12: LAKE ONTARIO CATEGORY 2 NORTHSHORE CLADOPHORA PRODUCTION FOR PLAN 6L

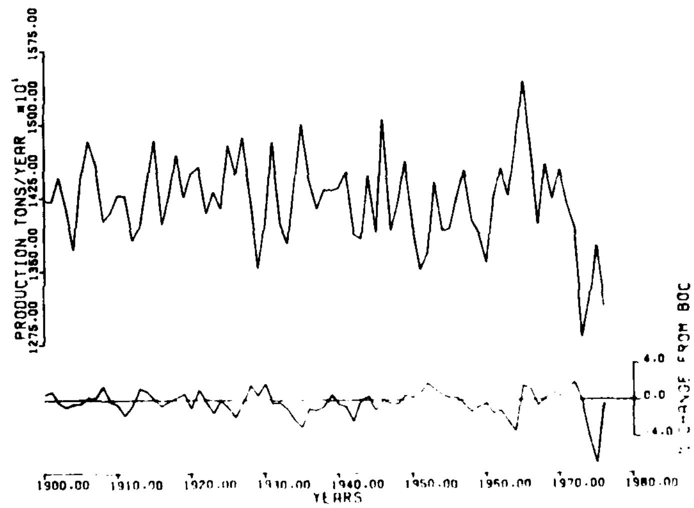

FIGURE F-13: LAKE ONTARIO CATEGORY 2 NORTHSHORE CLADOPHORA PRODUCTION FOR PLAN 155

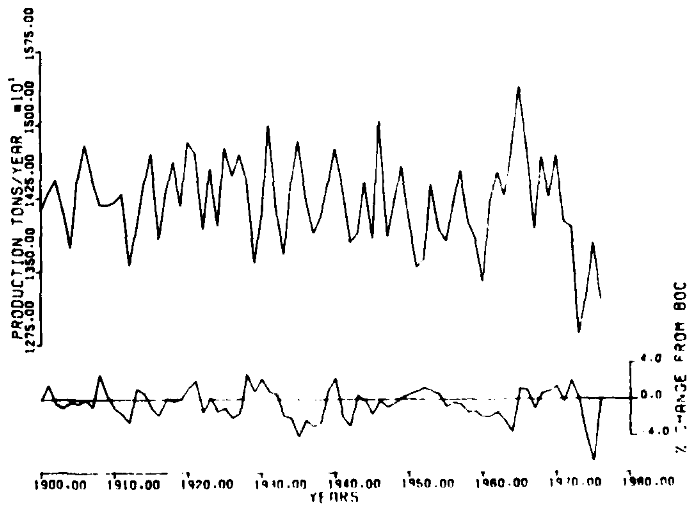

FIGURE F-14: LAKE ONTARIO CATEGORY 2 NORTHSHORE CLADOPHORA PRODUCTION FOR PLAN 25N

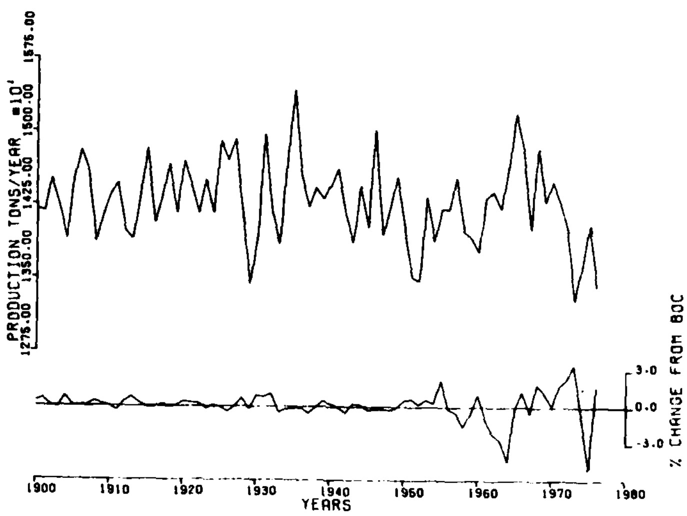

FIGURE F-15: LAKE ONTARIO CATEGORY 3 NORTHSHORE CLADOPHORA PRODUCTION FOR PLAN 6L

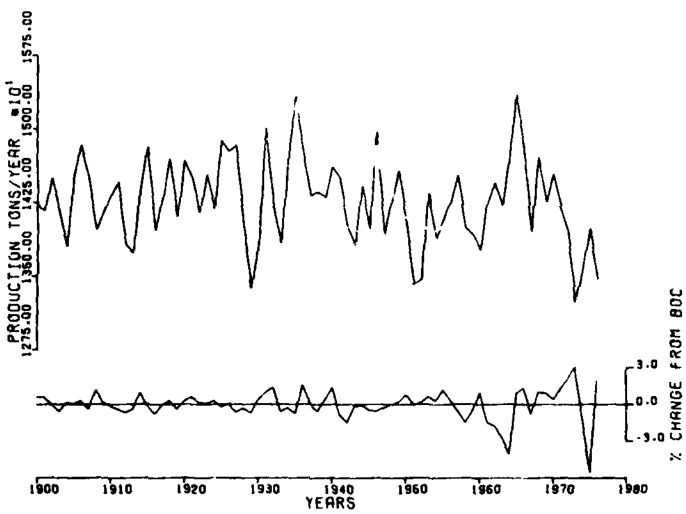

FIGURE F-16: LAKE ONTARIO CATEGORY 3 NORTHSHORE CLADOPHORA PRODUCTION FOR PLAN 15S

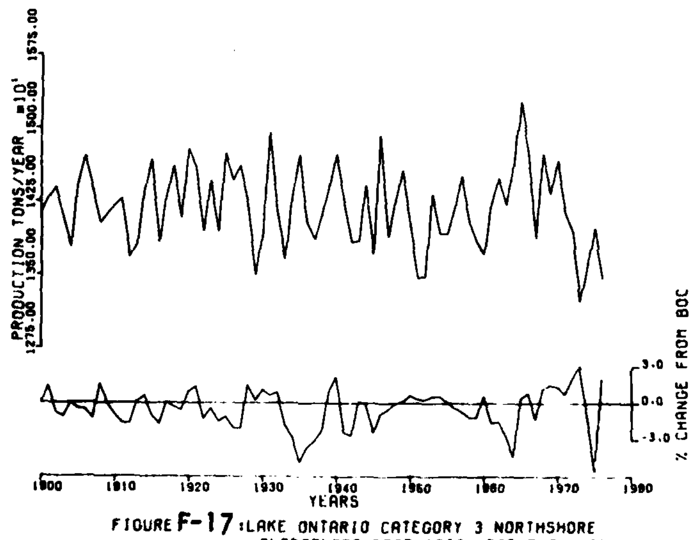

FIGURE F-17: LAKE ONTARIO CATEGORY 3 NORTHSHORE CLADOPHORA PRODUCTION FOR PLAN 25N

is buoyant under summer conditions and rises to the surface. Dilution is attained as a result of mixing action produced by the velocity momentum of the discharge and the rising movement. This phase is known as the initial or nearfield dilution.

During the winter when ambient water temperatures are less than $4^{o}C$, effluents experience what is commonly referred to as the plunging plume. Warm effluent rises and cools upon release to the receiving body, but as it cools past $4^{o}C$ it reaches its most dense state and sinks. As discussed below, the plunging effluent will receive the benefit of additional dilution before exposure to the receiving water surface (this is known as farfield dilution).

3.7.2 Implications of Lake Level Fluctuations

Reduced water levels may have an adverse impact in that a smaller volume of water in the nearshore zone would be available to dilute wastes from municipal and industrial outfalls. As a consequence, waste concentrations may be somewhat higher than experienced under BOC conditions. More efficient and costly treatment would then be needed to meet appropriate water quality standards. The adverse impact is less severe with a plunging plume in that the additional contact time with the receiving water, afforded by the plunge, alleviates the dilution capacity lost through lowered lake levels.

Initial dilution of effluents is influenced by the following factors:

1. depth of outfall;
2. wastewater discharge velocity;
3. discharge port size;
4. number of ports; and
5. temperature differential between receiving water and effluent.

Only outfall depth would be influenced by regulation.

3.7.3 Methodology

Published mathematical models (Abraham 1963) were reviewed and modified as necessary for this study. The study of sewers was disregarded since storm discharges are intermittent in occurrence and the quality of the discharge is relatively unknown. Outfalls which are five feet deep or less were considered to be surface outfalls and have small or zero initial dilution values. Outfalls which are approximately ten feet deep experience very little change in initial dilution (their original initial dilution values are low). The analysis focused on outfalls located in depths approximating 20, 30 and 40 feet. Miyamoto (1978) developed Figs. F-18 to F-21 which demonstrate the effects on dilution of a one foot decrease in depth. A decrease in initial dilution of less than two percent is considered to be within acceptable limits while a change of five percent or greater would be enough to cause concern.

Knowing the initial depth of the outfall, the velocity and diameter, Figs. F-18 to F-21 can be used to determine the change in dilution due to a one foot level decrease.

The analysis was confined to summer months since the plunging plume phenomena experienced in winter makes dilution independent of lake levels during that season.

3.7.4 Evaluation of Regulation Plans

For surface and near surface outfalls, a lowering of lake level of up to one foot would have little effect on dilution, yet may have aesthetic drawbacks due to exposure of outfall heads. Only Plan 25N would cause a lake level lowering that could appreciably compound existing aesthetic problems or cause new ones on Lakes Erie and St. Clair.

The majority of outfalls examined have diffuser systems which aid in the dilution and diffusion of effluents. Analysis of outfalls with diffusers indicates that existing dilution would not be changed significantly by any of the regulation plans.

There are a few single-port outfalls located in water ten feet deep or less in Lake St. Clair. However, the shallower areas are more susceptible to wind generated turbulence which aids in the dissipation of high waste concentrations.

For Lake Erie the maximum reduction in dilution would be less than two percent due to Plan 25N. The impact of Plan 6L and 15S would be proportionally less severe.

On Lake Ontario, along the Canadian shorelines, outfalls are fitted with diffusers. As indicated above, the dilution characteristics of these would not be appreciably affected by changing lake levels of the magnitude to be expected of Category 2 plans.

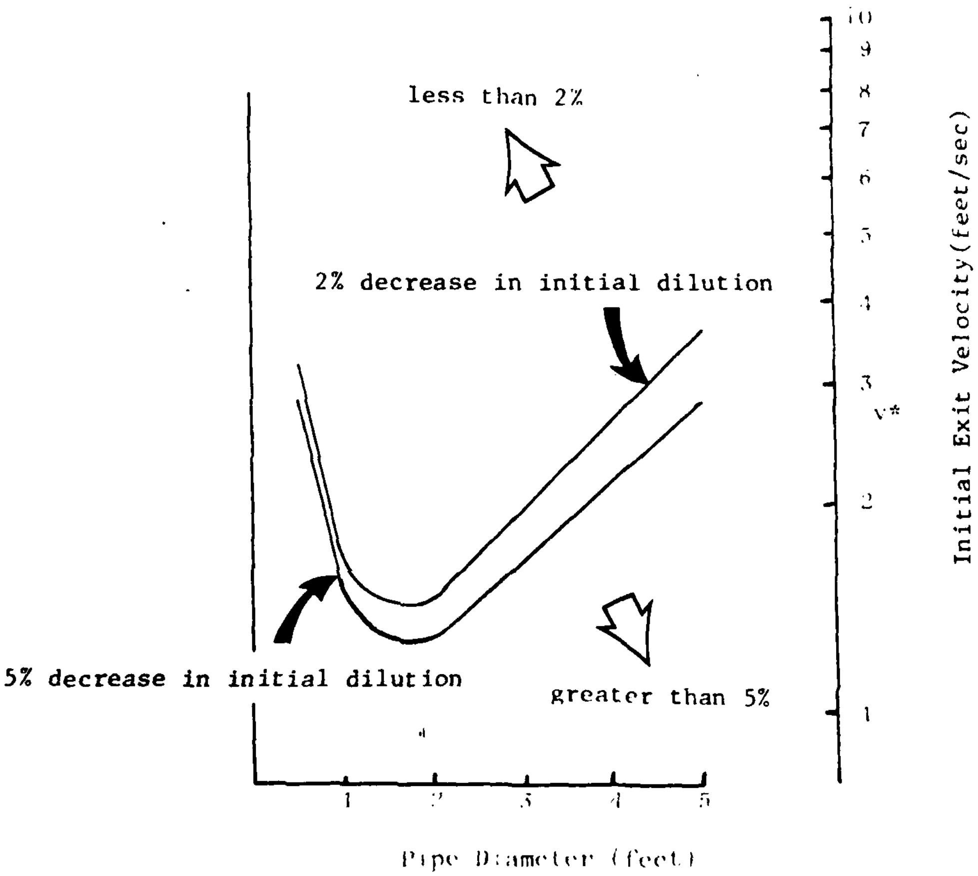

Figure F-18 The Effect of a one-foot Decrease in Water Level for an Outfall Without Diffusers at a Depth of 20 feet.

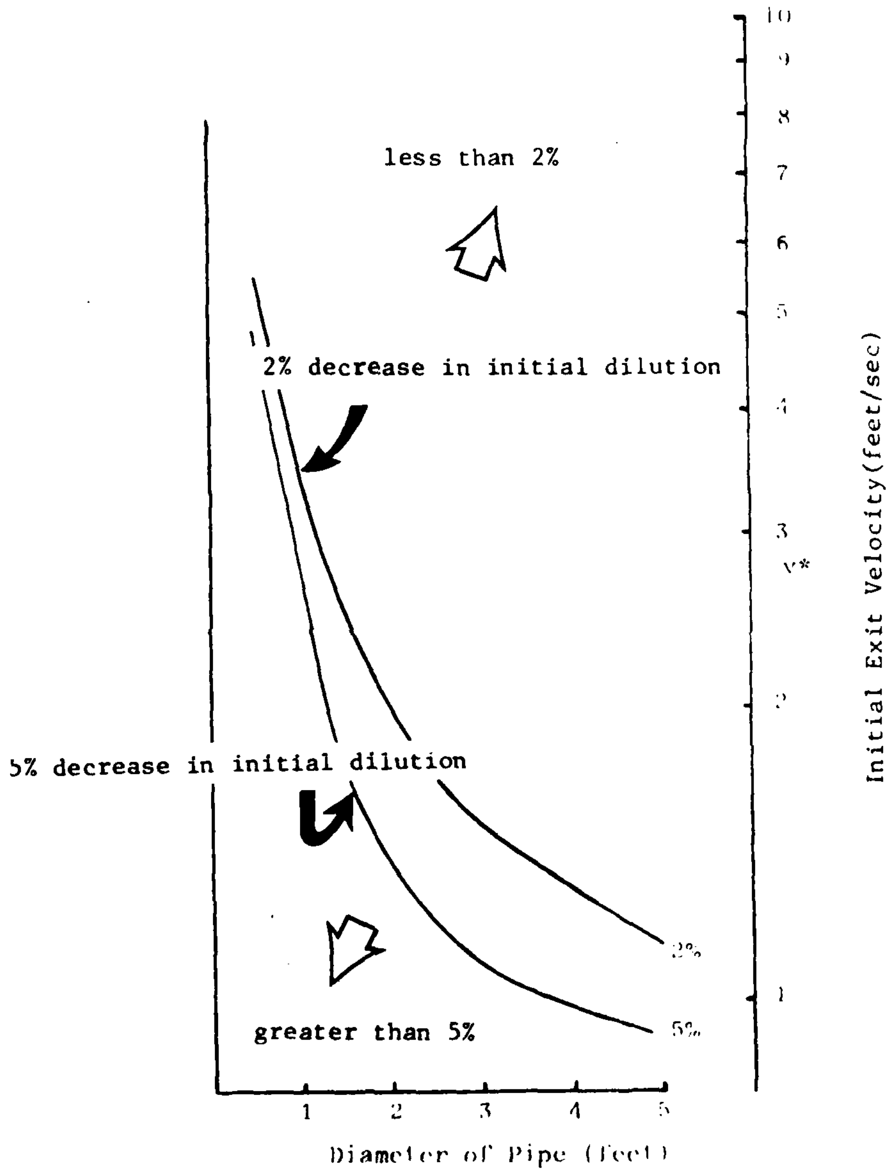

Figure F-19 The Effect of a one-foot Decrease in Water Level for an Outfall Without Diffusers at a depth of 30 Feet.

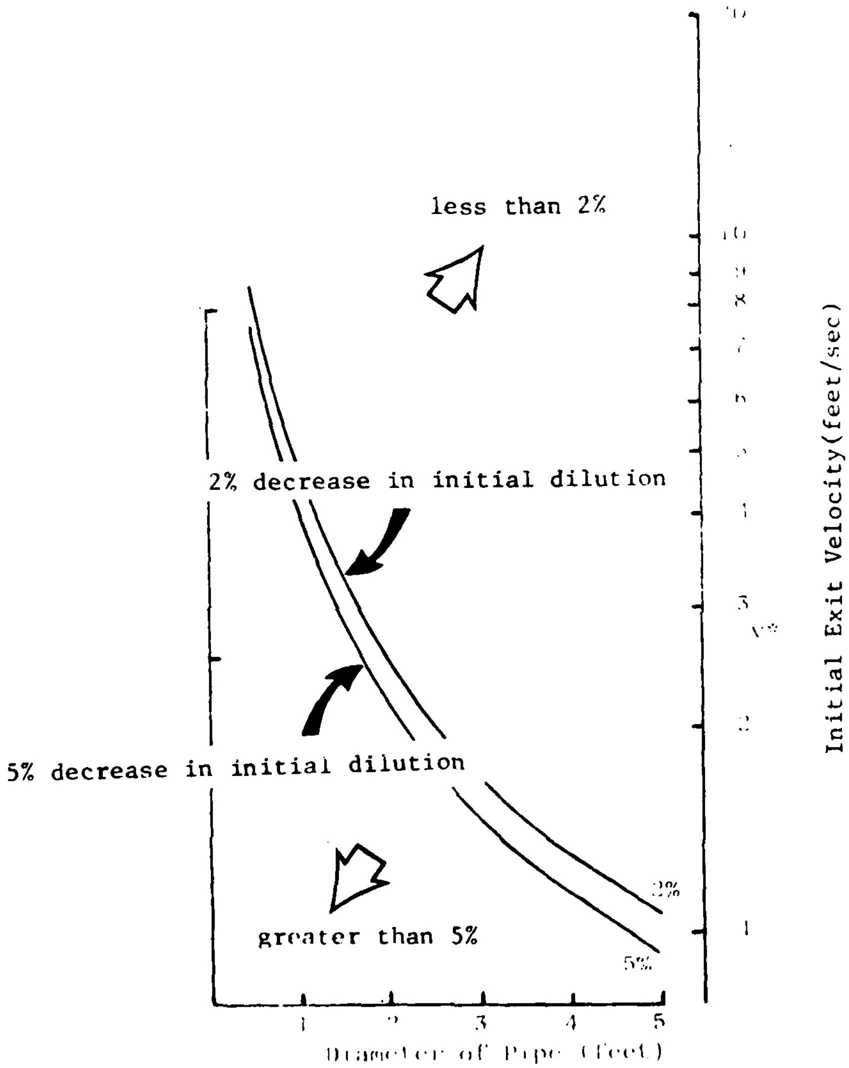

Figure F-20 The Effect of a one-foot Decrease in Water Level for an Outfall Without Diffusers at a Depth of 40 Feet.

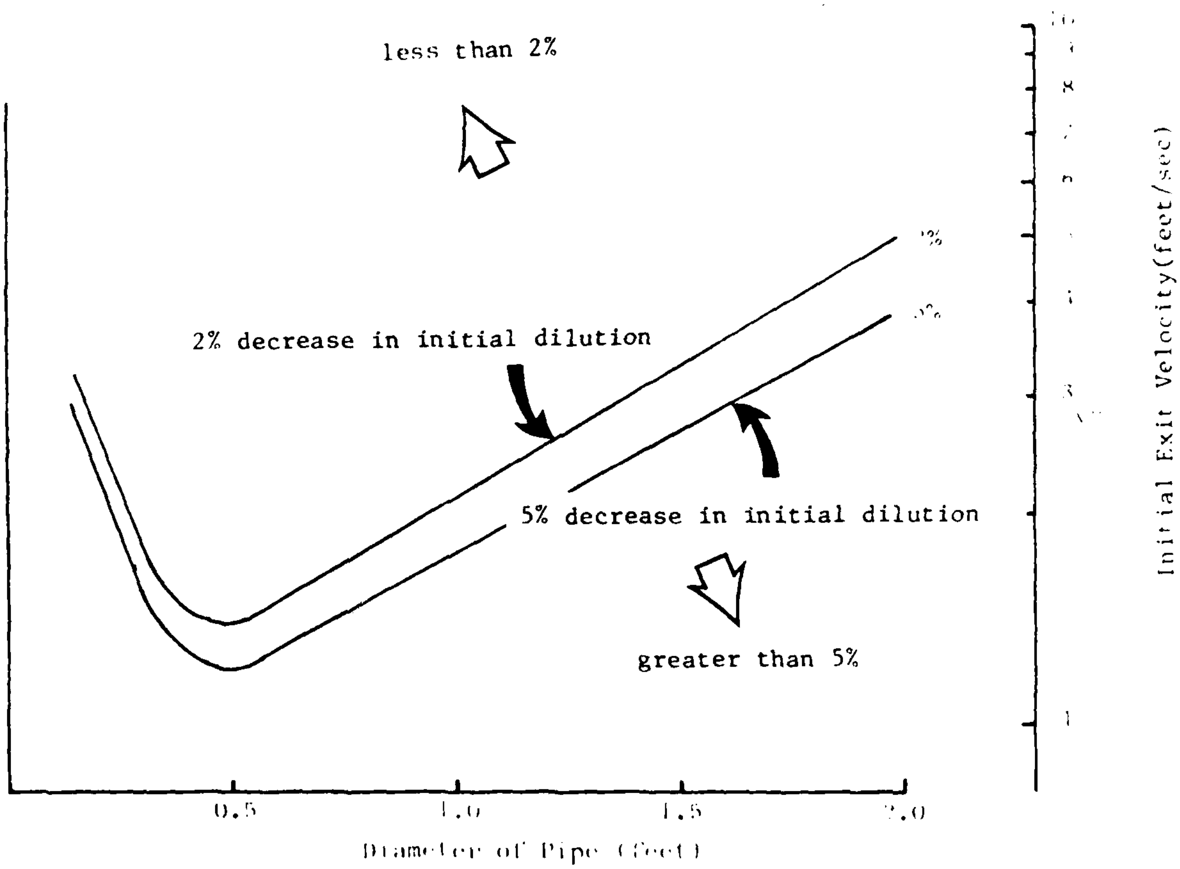

Figure F-21 The Effect of a one-foot decrease in water level for an Outfall With 10 Diffusers at a Depth of 20 Feet.

3.8 Phosphorus From Shoreline Erosion

3.8.1 Existing Conditions

Both natural and anthropogenic sources contribute significant amounts of phosphorus to aquatic systems. Anthropogenic sources include agricultural runoff, sewage, urban drainage, and industrial effluents. Important natural sources of phosphorus are precipitation, runoff, leaching, and shoreline erosion. Limited regulation of Lake Erie would have no effect on anthropogenic phosphorus inputs. It would not alter precipitation rates, runoff, or leaching, but would reduce shoreline erosion.

In general, shoreline erosion is the result of the attrition of unconsolidated bluff materials by the action of waves and by surface runoff. Erosion rates as high as 3m/yr. have been reported along the northshore of the Central Basin of Lake Erie (Gelinas and Quigley, 1973). These bluffs consist of clay-silt tills and range in elevation of up to 40 m above the Lake. These bluffs are without beach protection and, thus, are subject to wave action. Over a four or five year period of high water levels (1971-1974), this segment of the shoreline contributed approximately 21.2 million metric tons/year of fine-grained material to the sediment loading of Lake Erie (Kemp et al 1976).

As phosphorus is a significant constitutent of this bluff material (Williams et al 1976), shoreline erosion contributes a considerable load of phosphorus to Lake Erie. According to Burns (1976) and Williams et al (1976), at most, 6 percent of the total phosphorus input from shoreline erosion is biologically available. The IJC (1980) best estimate of the total 1976 phosphorus load to Lake Erie is 28951 metric tons of which 10526 metric tons are from shoreline erosion. Using the 6 percent Burn's estimate, this amounts to an input of 632 metric tons of available phosphorus to Lake Erie from shoreline erosion.

Logan estimates that 40 percent of the total phosphorus load from all sources (including shoreline erosion) to Lake Erie is in biologically available form. Applying this figure to the IJC best estimate of total phosphorus from all sources to Lake Erie (28951 metric tons) results in a total available phosphorus input of 11580 metric tons. The available phosphorus from erosion (632 metric tons) is approximately 5.5 percent of the available phosphorus from all sources.

3.8.2 Implications of Water Level Fluctuations

Nutritional overenrichment is one of the biggest problems on the lower lakes today. It is causing problems with water supplies, recreation, and fishing. Erosion contributes substantial amounts of phosphorus to the Great Lakes system. While the predominate form of erodible phosphorus is not biologically available (90-95 percent), at least initally, for use as a plant nutrient, the remainder (5-10 percent) is readily available for aquatic plant consumption.

3.8.3 Methodology

The eutrophication model developed by Vollenweider (1968) was adapted (Guppy, 1978) to determine mid-lake phosphorus concentrations in both Lakes Erie and Ontario:

$$P = \frac{J(1-R)}{Q}$$

where: P = calculated total phosphorus concentration in mg/m^3;
J = total available phosphorus loading in mg/year;
R = retention coefficient; and
Q = yearly lake outflow in m^3

For the purpose of the following analysis, the phosphorus loadings to Lakes Erie and Ontario as summarized in Table F-16 were taken from the 1976, 1977, and 1978 IJC Water Quality Surveillance Reports. Since total phosphorus contribution of shoreline erosion is available only for the year 1976, the 1976 erosion quantities were also applied to 1977 and 1978, even though based on a comparison of lake level data the quantities may be overestimated for the latter two years.

The retention coefficient is a measure of the proportion of phosphorus retained in the lake with respect to the total phosphorus load. In this analysis, the retention coefficients were determined both with and without the phosphorus contribution from erosional sources and are shown in Table F-17. The phosphorus loading data summarized in Table F-16 were used in the retention coefficient determinations.

The mean annual recorded outflows for both Lakes Erie and Ontario are listed in Table F-18.

As indicated by the Vollenweider Model, ambient phosphorus concentrations would change as a result of the change in phosphorus loading, although the response is not immediate. Dillon and Rigler (1975) have devised the following formulation to predict the time for a 50 percent change in concentration:

$$t\ 1/2 = 0.69\ (p + 10z)$$

where: $t\ 1/2$ = half-life time in years for 50 percent change in concentration;
z = mean lake depth in metres; and
p = flushing rate equal to total annual outflow rate divided by the lake volume.

In Lake Erie a steady-state condition would be reached in 3 to 5 times the half-life period (2-3 years). The lakewide phosphorus concentrations were determined by averaging the appropriate elements of the Vollenweider Model with the three year period, 1976 to 1978.

Table F-16

Summary Of Total Phosphorus Loads To Lakes
Erie and Ontario

SOURCE	Metric tons/year							
	Lake Erie				Lake Ontario			
	1976	1977	1978	Mean	1976	1977	1978	Mean
Direct Industrial Discharge	275	135	191	200	82	124	117	107
Direct Municipal Discharge	6292	5697	4440	5476	2093	2470	1913	2159
Tributary Monitored	9950	5285	10070	9790	4047	2413	2264	3305
Un-Monitored		1260	2804			557	635	
Atmospheric	774	1119	879	924	488	623	764	625
Load from Upstream Lake	1080	1080	1080	1080	4769	2748	5250	4256
TOTAL	18371	14576	19469	17472	11479	8935	10943	10452
Load in Outflow	4769	2748	5250	4255	4545	3854	4487	4295
Shoreline Erosion	10526	10526	10526	10526	1280	1280	1280	1280

Table F-17

Lakes Erie and Ontario Phosphorus Retention Coefficients

Lake	Year	Including the 100% Contribution Shoreline Erosion	Excluding the Contribution of Shoreline Erosion
	1976	0.83	0.74
	1977	0.89	0.81
Erie	1978	0.82	0.76
	Mean	0.85	0.76
	1976	0.64	0.60
	1977	0.62	0.57
Ontario	1978	0.63	0.59
	Mean	0.63	0.59

Table F-18

Mean Annual Recorded Outflows for Lakes Erie and Ontario

Lake	Year	x 100 cfs.	x 10^{11} m^3/year
	1976	245	2.188
	1977	223	1.991
Erie	1978	226	2.018
	Mean	231	2.066
	1976	300	2.679
	1977	262	2.340
Ontario	1978	275	2.456
	Mean	279	2.491

Table F-19 illustrates the concentrations predicted for Lakes Erie and Ontario assuming 0 percent and 100 percent of phosphorus from shoreline erosion is biologically available. The model best predicts the actual 1978 measured total phosphorus concentrations when the shoreline erosion contribution is excluded.

3.8.4 Evaluation of Regulation Plans

As shown in Table F-7 all of the regulation plans would reduce long-term erosion on Lake Erie. Under Plan 25N, erodible material from Lake Erie bluffs and the phosphorus associated with those materials would be reduced by approximately 18 percent. Based upon the IJC estimates for 1976, the 632 metric tons of available phosphorus from erosion would be reduced by 114 metric tons. This reduction would be 1 percent of the available phosphorus discharged from all sources (11580 metric tons).

Mid-lake total phosphorus concentrations were determined with the model using the regulation reduced phosphorus inputs but with the retention coefficient (R) and the lake outflow (Q) unchanged. It is unlikely that regulation would appreciably change R and Q. The predicted (under regulation) total phosphorus concentrations (Table F-19) would not change significantly from those calculated for the base case even under 25N. Phosphorus concentrations under 6L and 15S would change even less.

Similar analyses for Lake Ontario indicate no appreciable concentration change from the base case.

3.9 General Water Quality

3.9.1 Methodology

Sufficient data did not exist to relate general water quality to varying lake levels. It was therefore necessary to model a conservative parameter such as chloride to arrive at an estimate of such a relationship. The concentration of chloride in Lake Erie was determined based upon the following model:

$$\text{TOTAL CHLORIDE} = \frac{\text{DETROIT RIVER LOADING}}{0.744} \times \underset{\text{(DAYS)}}{\text{RESIDENCE TIME}}$$

$$\text{LAKEWIDE CHLORIDE CONCENTRATION (mg/1)} = \frac{\text{TOTAL CHLORIDE}}{\text{LAKE VOLUME}}$$

Chloride concentrations were calculated for three lake levels on Lake Erie. These levels bracketed the maximum range of lake level changes expected under the regulation plans. A range of residence times was also investigated (Table F-20).

Changes in chloride concentrations may occur because of two events associated with lake level regulation: 1) the volume of water in Lake Erie would be reduced while the inputs would be unaffected, and, 2) a longer residence time will allow a greater accumulation of these materials in the lake.

Table F-19

Predicted and Measured Lake-wide Total Phosphorus Concentration for Lakes Erie and Ontario

(mg/m^3)

	Lake Erie	Lake Ontario
Phosphorus Concentration Assuming No Shoreline Erosion Contribution	20.29	17.20
Phosphorus Concentration Assuming 100% Shoreline Erosion Contribution	20.33	18.91
Measured Mean Phosphorus Concentration (1978)	19.7[1]	17.8[2]

1. International Joint Commission, 1979, Great Lakes Water Quality 1978 Appendix B Surveillance Subcommittee Report

2. Ibid.

Table F-20

Lakewide Mean Chloride Concentration for Lake Erie (mg/l)

Lake Levels - Feet, (IGLD)

	1974			1976		
Residence Time (yrs)	573.5	570.5	567.5	573.5	570.5	567.5
2.0	18.78	19.69	20.69	16.58	17.39	18.27
2.2	20.65	21.66	22.76	18.24	19.13	20.10
2.4	22.53	23.62	24.83	19.90	20.86	21.92
2.6	24.41	25.59	26.90	21.56	22.61	23.76
2.8	26.29	27.56	28.97	23.22	24.34	25.59

The concentration of any conservative material in a lake should reach an equilibrium between the inputs and residence time (Vollenweider 1968). Thus, as long as the total amount of material entering the lake does not change, the lake-wide concentration will ultimately equal the input concentration. This concept works well in small lakes where the residence time is only a few days or months; these residence times are short enough to preclude any major changes in dissolved solids entering the lake. However, the Great Lakes, with their long residence time (2.4 years for Lake Erie to over 600 years for Lake Superior) experience considerable changes in the total dissolved solids load within one residence time. Over the past twenty years, Lake Erie has seen a vast increase in loadings followed by a moderate decrease (Sonzogni et al. 1978). As a result, an equilibrium between inputs and lake-wide concentration has not been reached. This analysis has been based on the concept that an equilibrium will be reached in Lake Erie, although this seems unlikely in the next ten years.

3.9.2 Evaluation of Regulation Plans

Burns (1976) indicates the Detroit River flow contributes about 74 percent of the total chloride load to Lake Erie and the average residence time for Lake Erie is 2.4 years. Using lake volumes anticipated under the range of lake levels for BOC and the regulation plans and residence times associated with these volumes, an average lake-wide chloride concentration was calculated. The results of the calculation show that for two years, 1974 and 1976, a one foot lowering of the water level in the lake would amount to slightly more than 0.3 mg/l increase in chloride concentration. This is an increase of approximately 1.5 percent over the current average lake-wide chloride concentration of 20.8 mg/l.

The largest water level changes with the regulation plans should have only a minimal effect on Lake Erie chloride concentrations. Furthermore, the plans would not have a consistent effect. Residence times would be reduced during some periods (increased outflows) and not changed during others. Thus, the effect of regulation would be an increase in chloride concentration when water levels are lower and a reduction in chloride concentration when residence times are shorter. However, the net effect of the plans should be minimal due to the interaction of lake levels and residence times.

Other conservative parameters such as sulfate, carbonate, bicarbonate, dissolved metals, etc., would be affected similarly. Mid-lake nutrients such as nitrogen and silica are most difficult to characterize in relation to lake level changes since the effects of biological uptake, adsorption, sedimentation, and other environmental phenomena would be comparatively so large as to make lake levels effects inconsequential.

Based upon the above discussion, general mid-lake water quality would be affected very little by the lake lowerings associated with the regulation plans under study.

3.10 Effects Of Regulation On The St. Lawrence River

3.10.1 Existing Conditions

The outflow of Lake Ontario is controlled by the Moses-Saunders Power Dam and the Long Sault Dam upstream of Cornwall according to Plan 1958-D. Plan 1958-D incorporates outflow limitations to protect downstream interests, maintain minimum flows, avoid quarter-month flow adjustments in excess of 20,000 cfs, and limit maximum flows.

Under Plan 1958-D, the maximum permissible flow is 310,000 cfs when Lake Ontario levels exceed 246 feet. However, as in the 1970's record high supplies to Lake Ontario have resulted in deviation from the Plan with flows of up to 350,000 cfs.

With respect to water quality the St. Lawrence River Study Committee (1977) identified four major types of degradation:

1. toxic substances contamination;
2. bacteriological contamination;
3. excessive suspended sediment; and
4. excessive nutrient enrichment.

The St. Lawrence River Study analysis focused on the St. Lawrence River downstream from Cornwall. Throughout the study area, elevated coliform concentrations have been a problem, especially around Montreal and downstream. Field investigations in the Montreal area have identified coliform densities exceeding the recommended maximum levels for public water supplies. The dissolved oxygen concentration in the Lower St. Lawrence River averages approximately 6 mg/l (70% saturation). Although the dissolved oxygen saturation concentrations are relatively high the 30% oxygen deficit represents a substantial portion of the potential total oxygen reserves which can signify potential future problems (Surveyor et al. 1973).

Local water quality problems occur in the form of bacteriological contamination, nutrient enrichment, suspended sediment and organic contamination, but are quickly dissipated. Local problems usually occur since wastes are confined to the nearshore areas by the current (Surveyor et al 1973). In many instances it is necessary to measure the distribution across the river to obtain a representative average concentration.

3.10.2 Implications of Lake Erie Regulation

The discharge of excess water from Lake Erie under various Category 2 plans would cause increases in mean Lake Ontario levels by 0.05, 0.08 and 0.10 feet under Plans 6L, 15S and 25N, respectively. In order to accommodate Lake Erie regulation under Category 2, Plan 1958-D was modified. The change in the flow regime would potentially impact water quality through changes in dispersion characteristics and in erosion and suspended sediment concentrations.

3.10.3 Methodology

Calculations using the 2-gauge, stage fall relationship developed by the International St. Lawrence River Board of Control indicate that the water surface profile from Lake Ontario to Cornwall is dependent upon Lake Ontario levels more than flows. The change in mean velocity under various flows and levels has been investigated by using the NOAA Upper St. Lawrence River Hydraulic Transient Model (1978).

3.10.4 Evaluation of Regulation Plans

Table F-21 lists the mean monthly St. Lawrence River flows for the BOC and Lake Erie regulation plans, and the flow difference between the regulation plans and BOC. In general, the flow differences increase during winter months and decrease during summer months. The maximum flow for all plans would be reduced from 350,000 cfs to approximately 326,000 cfs, and the minimum flow would be 188,000 cfs compared to the BOC minimum flow 176,000 cfs.

The variation in water quality of the St. Lawrence River has been noted in the annual surveys of the International Joint Commission (IJC). Table F-22 indicates the variations in concentration during 1977 of some of the commonly measure parameters (IJC 1978). During the period 1968 to 1973 the chloride concentration varied from 27.6 to 28.5 mg/l while the St. Lawrence River flow varied from 221,000 to 350,000 cfs. The percentage variation in the concentration (approximately 3%) is substantially lower than the percentage variation in flow (58%).

Bearing in mind that the maximum deviation in flow from BOC is less than ± 17 percent, the prediction of changes in water quality could not be made with any confidence. The changes in flow become less pronounced below Montreal once the flow from the Ottawa River and other tributaries are considered.

In local areas the existing dispersion of effluents from outfalls may be slightly changed. During periods of higher flow the dispersion plumes could be extended longitudinally downstream with concommitant lateral reductions. However, should the higher flow cause increased turbulence and mixing the dispersion plume may not be extended at all. Estimating the precise limits of plumes extension potential would require a substantial quantity of data, beyond the scope of this study, and subsequently was not attempted.

The NOAA St. Lawrence River hydraulics model was modified to provide mean velocity in reaches defined for the model simulation. Table F-23 lists the conditions for which the model was run and the resultant mean maximum river velocity north of Gallop Island. The listed velocities would be for a uniform cross-section. Maximum velocities of up to five feet per second have been observed, depending upon location.

The 1970 soil plan of the St. Lawrence Seaway Authority indicates that from Brockville to Montreal the river bed is composed primarily of hard clay, shale, glacial till and rock. Very little scourable sediment is found in this area. The predicted increases in mean velocity would not generate any substantial change in the bottom shear velocity. No significant alteration of existing river bed scouring patterns would be anticipated.

3.10.5 Conclusions

While changes in water quality of the St. Lawrence River related to water level regulations cannot be predicted with confidence, it appears that overall water quality would benefit slightly under Category 2 Plans. The

TABLE F-21

Monthly Mean St. Lawrence River Flows

(T cfs)

	CATEGORY 2 Plans						
	Basis-of-Comparison	6L	Difference (Plan-BOC)	15S	Difference (Plan-BOC)	25N	Differece (Plan-BOC)
January	216.53	218.36	1.83	218.18	1.64	216.84	0.31
February	228.08	228.60	0.53	228.84	0.76	228.18	0.10
March	233.39	231.98	-1.41	233.34	-0.05	231.61	-1.78
April	240.17	241.39	1.22	243.11	2.94	241.57	1.40
May	247.26	247.81	0.56	249.46	2.20	249.04	1.76
June	252.55	251.48	-1.06	251.63	-0.92	252.68	0.13
July	256.36	255.37	-0.99	254.72	-1.65	256.92	0.56
August	257.83	256.38	-1.45	255.05	-2.78	258.13	0.30
September	255.08	253.96	-1.11	252.80	-2.28	255.00	-0.08
October	247.92	247.27	-0.65	246.43	-1.49	247.08	0.84
November	240.34	240.17	-0.17	239.85	-0.48	240.39	0.05
December	230.70	232.94	2.23	233.30	2.60	232.92	2.21

Table F-22

Upper St. Lawrence River Water Quality Data
For 1977 (IJC 1978b)

Parameter	Mean	Range
Total Phosphorus	0.020 mg/L	-
Ammonia	0.010 mg/L	0.026 - 0.040 mg/L
Nitrate	-	0.250 - 0.060 mg/L
Total Kjeldahl Nitrogen	-	0.200 - 0.310 mg/L
Specific Conductance	315 microsiemens	-
Chloride	-	25.8 - 28.1 mg/L

Table F-23

Hydraulic Model Simulation Conditions

Hydraulic Model Simulation Conditions		
Flow (cfs)	Lake Ontario Levels (feet)	Maximum Velocity (fps)
330,000	247.82	3.91
310,000	247.82	3.64
272,000	243.73	3.61
233,000	243.72	3.03
212,000	245.96	2.55
241,000	245.73	2.94

increased erosion occurring during extreme high water flow and the reduced dilution capacity during the extreme low flow would be tempered under all regulation plans, as compared to BOC since the long-term extremes in water flow range would be dampened.

3.11 Structural Effects On The Niagara River

3.11.1 Existing Conditions

The major pollution load to the Niagara River stems from the nutrient input of Lake Erie, industrial and municipal wastes carried by the Buffalo River, and direct waste input from riparian industries and municipalities in the Buffalo Metropolitan Area. Due to the large volume of Lake Erie water in the river, the effect of most pollutants contained in directly discharged wastes is masked by a high dilution ratio. According to the Great Lakes Basin Freamework Study (1975), more than 1.4 billion gallons of municipal and industrial wastes are directly discharged into the upper Niagara River each day. This figure does not include Canadian discharges or discharges from the Niagara Falls area. A low flow of 168,000 cfs would result in a flow/waste dilution ratio of about 76:1. Major pollutants of the Niagara River include coliform, bacteria, phenol, oils, sulfate, chloride, ammonia and excess organic loadings with related dissolved oxygen depletions. High velocities cause the confinement of polluted waters to the shores of the Niagara River.

Water quality in the Niagara River within the vicinity of Squaw Island-Bird Island generally exhibits two distinct patterns. High quality waters can be found adjacent to the Canadian shoreline in this reach while most of the polluted waters are either directed through the Black Rock Canal or along the east bank of the river. In addition, primary treated sewage is discharged into the river at about the mid-point of Squaw Island, adding to water quality degradation in this reach of the river.

3.11.2 Niagara River Alternative

The Niagara River alternative would increase the flow by enlarging the cross sectional area of the river at the Peace Bridge. An area of about 710 feet (width) and 3,000 feet (length) would be dredged adjacent to Squaw Island. A control structure consisting of six gates (75 ft. each) would be constructed to regulate the flow.

Construction activities, including the erection of a cofferdam, extensive excavation of the river bottom and erection of the control structure, would increase suspended solids concentration down-river of the construction site. Within the area delineated for excavation, the river velocities is about 12 feet per second. The likelihood of experiencing fine-grained material, to which toxic substances usually adhere, is minimal. Suspended solids which are generated would originate from cofferdam installation/removal and/or excavation of rock. However, both of these construction effects should be temporary. Upon completion of the project, suspended solid loading would return to normal levels.

The completed structure, along with the enlarged cross section of the river, could change the flow characteristics and also alter current patterns below the Peace Bridge. Due to the existing high velocities, the potential for increase of suspended solids is minimal. Higher velocities would tend to confine the pollutants originating on the U.S. side of the River, towards the U.S. shore.

3.11.3 Black Rock Canal Alternatives

The Black Rock Canal alternatives involve either a diversion channel across Squaw Island or modifications to the existing Black Rock Navigation Lock.

Construction activities required for a Black Rock Lock alternative would have a minimal effect on the quality of water in the Niagara River. Construction associated with dredging and bank modification would increase suspended solids in the Canal. All of these effects would be confined to the construction phase.

The most significant effect of the implementation of either plan would be an increase in velocity in the Black Rock Canal. Most stretches of the canal area are presently in a rather stagnant condition, flow is trivial, and limited to periods when the lock is open. The Canal bottom is apparently covered with mud and silt. Anoxic conditions develop in several areas along the Canal. Regulation would increase the velocity of flow in the Canal by 0.7 to 1.7 m/sec, depending upon the capacity of the structure. Black Rock Canal water quality would improve dramatically during periods when part of Lake Erie outflow is being diverted through the Canal (Fraser 1972).

The particle diameter versus critical scour velocity curve, used by Moll et al. (1979), indicates that all particles smaller than 1.0 mm in diameter would be scoured from the entire Canal if the water velocity was increased by 0.7 m/sec. Essentially, all silt, mud, and sand particles now present in the Black Rock Canal would be transported into the Niagara River. A significant portion could reach Lake Ontario.

Besides causing a substantial increase in suspended solid loadings, the resuspension and transport of these particles could result in the release into the Niagara River and Lake Ontario of a significant portion of any toxic substances contained in the sediments of the Black Rock Canal (Plumb and Sweeney, 1980). The increased suspended solid loadings would be substantial, but would continue only until the canal is scoured clean of sediments. However, there may be extended time periods when the canal is not being used during low water periods. Such periods would allow sediments to reaccumulate in the Black Rock Canal only to be scoured out when the regulatory works are used again. The effects of disturbing the various toxic substances could not be predicted at this time, due to incomplete data regarding present pollutant loading conditions.

3.11.4 Conclusions

It appears that of the regulatory works to increase the outflow from Lake Erie, the Niagara River site would prove least harmful to water

quality. Detrimental water quality effects (primarily turbidity) resulting from the implementation of this alternative would be temporary and would be caused mainly by construction activities. The Niagara River site would not greatly alter the present aquatic environment of the Niagara River, the Black Rock Canal or Lake Ontario.

The increased flow through the Black Rock Canal would substantially improve the aquatic environment through the Canal, but also has the potential to increase the release of contaminated sediments into the Niagara River. Contaminated materials released to the Niagara River could circulate in the eddies (backwash areas) that occur in that region. Dispersion could be incomplete, increasing the likelihood of toxicant, nutrient, and/or pathogen accretion. At the present time the canal functions as a sink in which many pollutants, originally discharged to the Buffalo River and Scajaquada Creek, settle out and eventually (annually) are removed by navigation maintenance dredging.

3.12 Summary

A summary of the potential systemic effects related to water quality which could be expected upon implementation of the regulation plans is shown on Table F-24. The biggest impacts, both adverse and beneficial, would result from the Plan 25N.

The most significant impact of lowered lake levels would be related to the reduction in embayment volume in shallow embayments with a small lake-bay interface. The associated dilution capacity loss would increase the potential for embayment pollutant concentration. This condition could be critical in the event of a "slug" pollutant load (e.g., accidental spill, bypass due to equipment malfunction, etc.). On the other hand, lowered lake levels would enhance the effects of water exchange between lake and bay (which aids to dilute contaminants). However, the latter process is periodic and not appropriately significant to adequately neutralize the adverse effects on water quality of embayment volume (dilution capacity) loss.

All the regulation plans would reduce nearshore turbidity provided that erosion would be reduced with regulation. The projected mean turbidity decreases would be relatively small.

All Plans would slightly increase the long-term annual mean Cladophora production in Lake Erie. No appreciable effect on Cladophora production in Lake Ontario is expected.

Limited regulation of Lake Erie would not significantly affect the quantity of water available for dilution of wastes emanating from nearshore outfalls. However, some aesthetic drawbacks in the nearshore area may be noticed due to the possible exposure of outfall heads. Lakes Erie and Ontario water quality generally would not be significantly altered by any regulation plans

Table F-24

- Summary of Systemic Effects of Regulation Plans on the Water Quality Characteristics in Lake Erie

Characteristics	Probable Effects	Plan 6L	Plan 15S	Plan 25N
Hypolimnion	Onset of stratification affected by depth of water column.	Negligible	Negligible	Negligible
	Reduction in hypolimnion volume:			
	Western Basin	No Hypolimnion	No Hypolimnion	No Hypolimnion
	Central Basin	Unknown Significance	Unknown Significance	<15% Reduction
	Eastern Basin	Unknown Significance	Unknown Significance	3.4% Reduction
	Change in dissolved oxygen concentration.	Negligible	Negligible	Negligible
Turbidity	Reduction in mean annual turbidity. (Elgin Area 1967-1976)	2% Reduction	5% Reduction	11% Reduction
Embayments	Increase in pollution concentrations due to lowering effect. (Assuming depth of 6 feet.)	1.5%	4.0%	10.9%
	Decrease in pollutant concentrations due to wind setup. (Assuming BOC depth of 6 feet.)	0%	0.2%	0.7%
	(For embayments deeper than 6 feet.)	Negligible	Negligible	Negligible
Cladophora Production	Increase in mean annual production:			
	Western Basin (Bass Islands)	0.5%	1.4%	2.7%
	Central Basin	No Significant Growth	No Significant Growth	No Significant Growth
	Eastern Basin (North Shore)	0.1%	0.3%	1.1%
Waste Outfall Dispersion	Effects restricted only to outfalls without diffusers.	Negligible	Negligible	Negligible
Phosphorus	Reduction in sediments from shoreline erosion, lakewide.	Negligible	Negligible	Negligible
General Water Quality	Inflows, outflows, and detention period.	Negligible	Negligible	Negligible

Section 4

WILDLIFE/WETLANDS

4.1 Introduction

Evaluation of the effects of the Lake Erie regulation plans on wildlife was achieved by examining the changes in wildlife habitat that may occur as a result of altered lake level regimes. The greatest impact of lake level changes would occur along the shores and shallow areas of the Great Lakes where wetlands are the primary type of wildlife habitat. Cowardin et al. (1977) consider wetlands to be lands where "the water table is at, near or above the land surface long enough each year to promote the formation of hydric soils and to support the growth of hydrophytes, as long as other environmental variables are favorable".

Evaluation of the impacts of lake level regulation on wildlife was directed principally to Lakes Erie and St. Clair (including the Detroit and St. Clair Rivers). These lakes contain a large proportion of the most important wetland habitat in the Great Lakes system and would experience the most severe changes under regulation. The predicted impacts of water level alterations on Lake Ontario and the St. Lawrence River to the Ontario/Quebec border were also addressed, as were the effects of structural and remedial works considered for the Niagara and St. Lawrence Rivers.

The wildlife evaluation was largely qualitative. Some of the predicted impacts were based on judgements of biologists familiar with Great Lakes wetlands, not on detailed scientific studies. Detailed information on bottom contouring of wetlands was not available and information linking vegetative changes in the Great Lakes wetlands to water level fluctuations was very limited. Studies correlating the responses of wildlife species with water level fluctuations and with the resultant vegetative changes in the wetlands of the system were almost non-existent.

4.2 General Approach

The wildlife evauation predicted the effects that the three regulation plans could have on the long-term (i.e., over 4 years) and short-term (i.e., 4 years or less) vegetative structure of shoreline wetlands, their value as wildlife habitat and on specific wetland types.

As a first step, the shoreline wetlands in the study area were inventoried according to a classification scheme designed for this study. Seven wetland types, illustrated in Fig. F-22 have been defined based on physical characteristics and general predicted responses to water level changes. The seven types represent wetland situations ranging from completely protected (#7). The classification system used was adopted with some modification from the 1973 International Great lakes Levels Board Study.

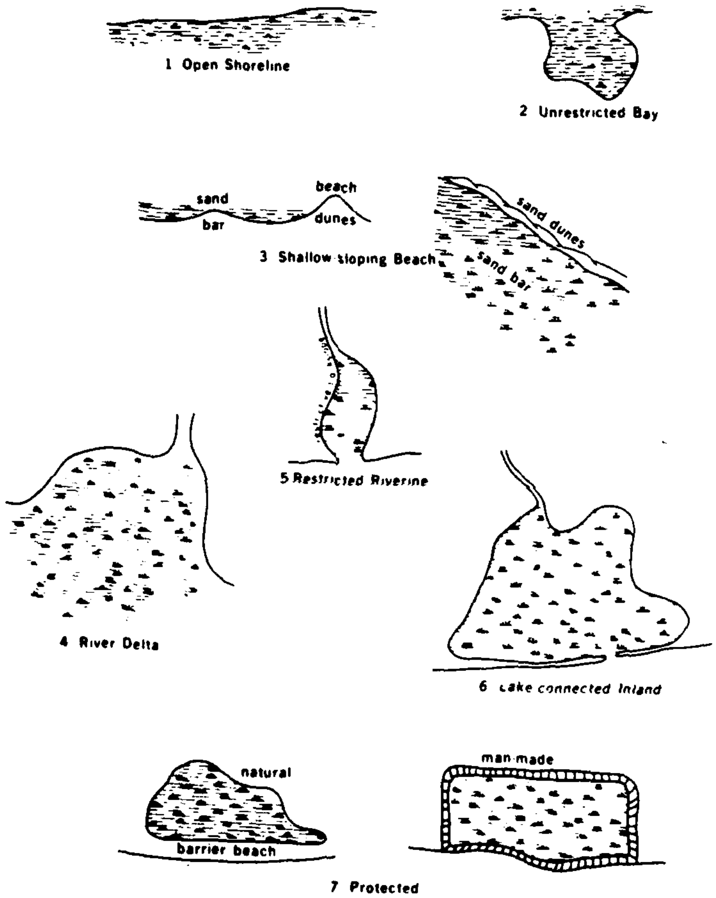

Figure F-22:Pictorial representation of seven Wetland Types.

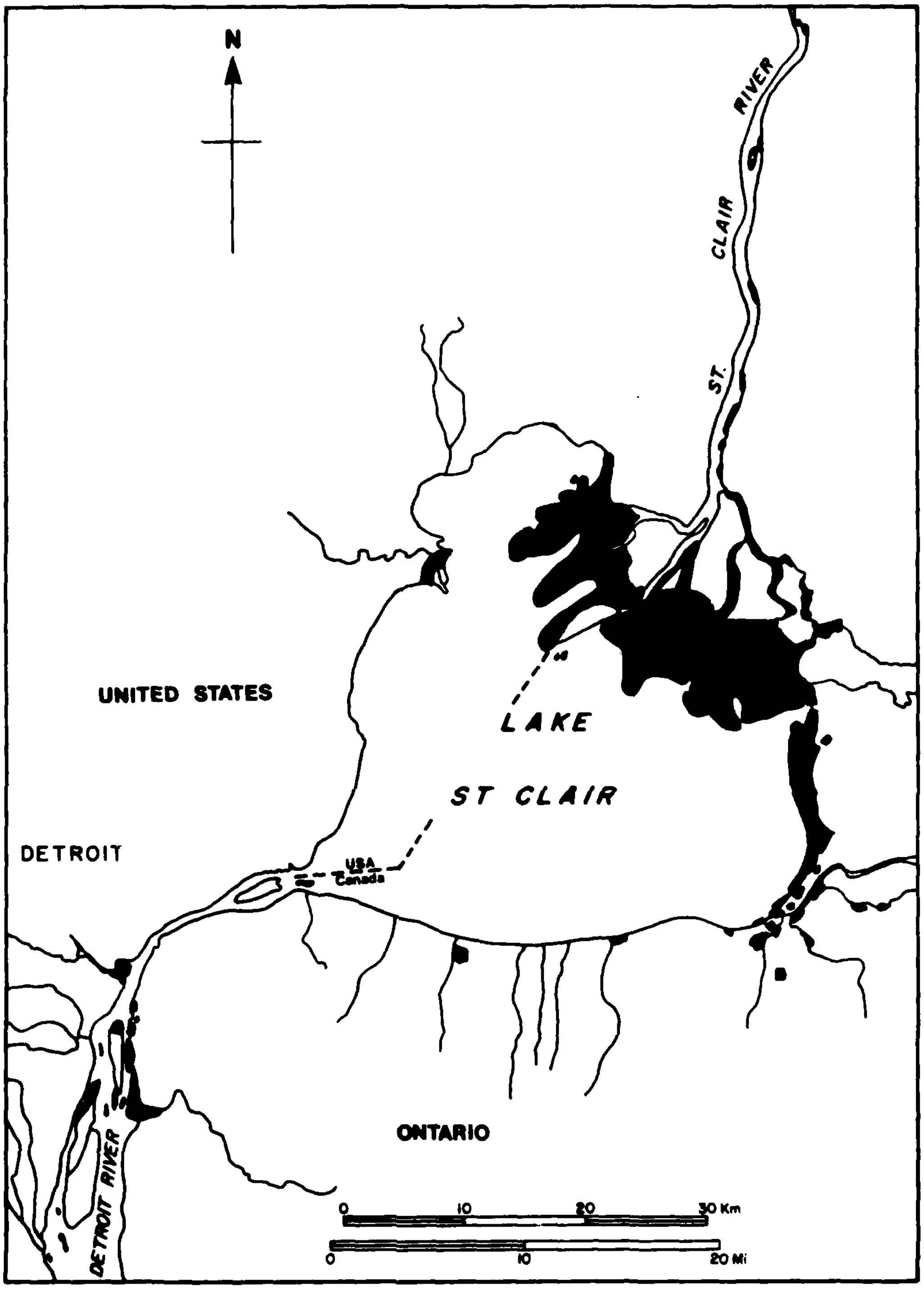

Figure F-23: Wetlands of Lake St. Clair.

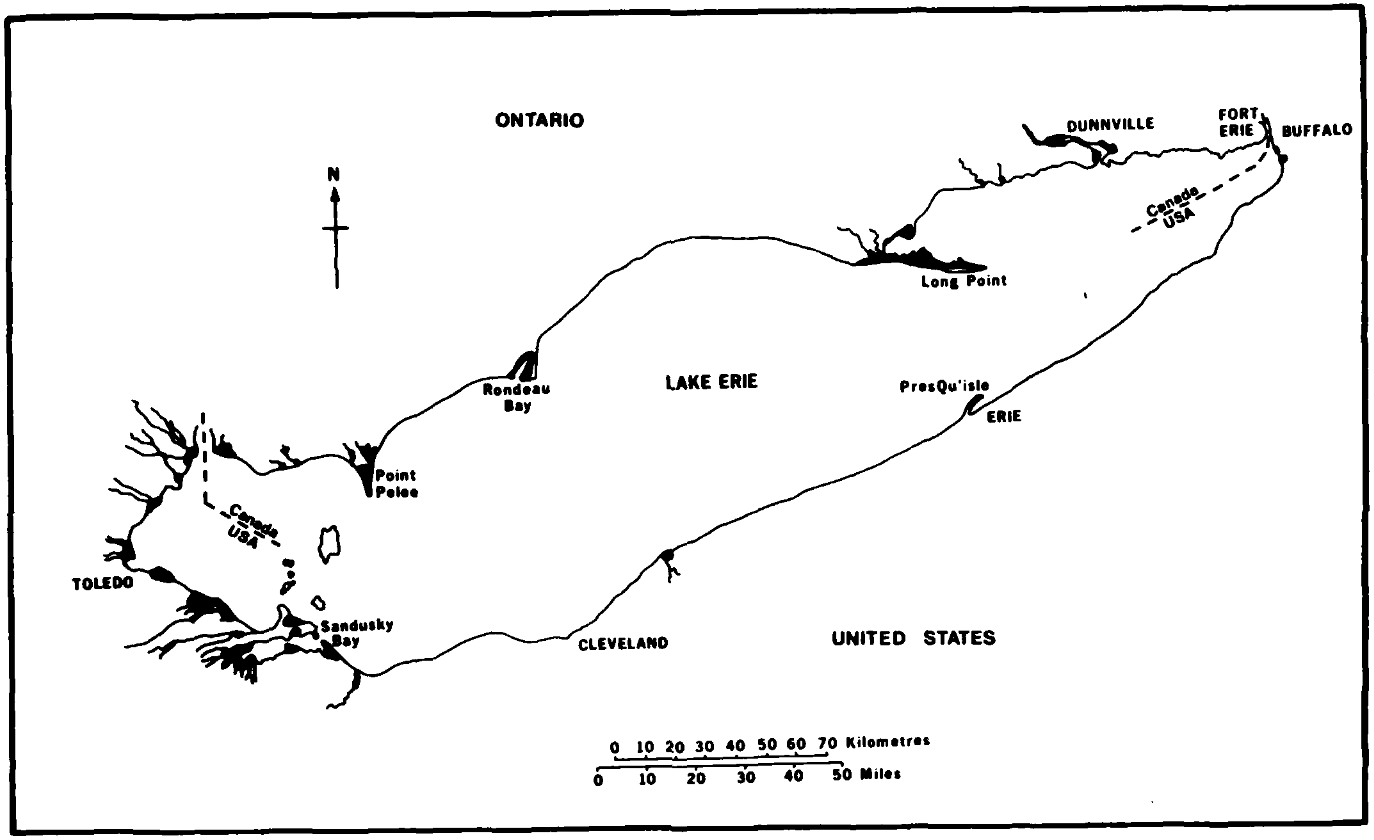

Figure F-24: Wetlands of Lake Erie

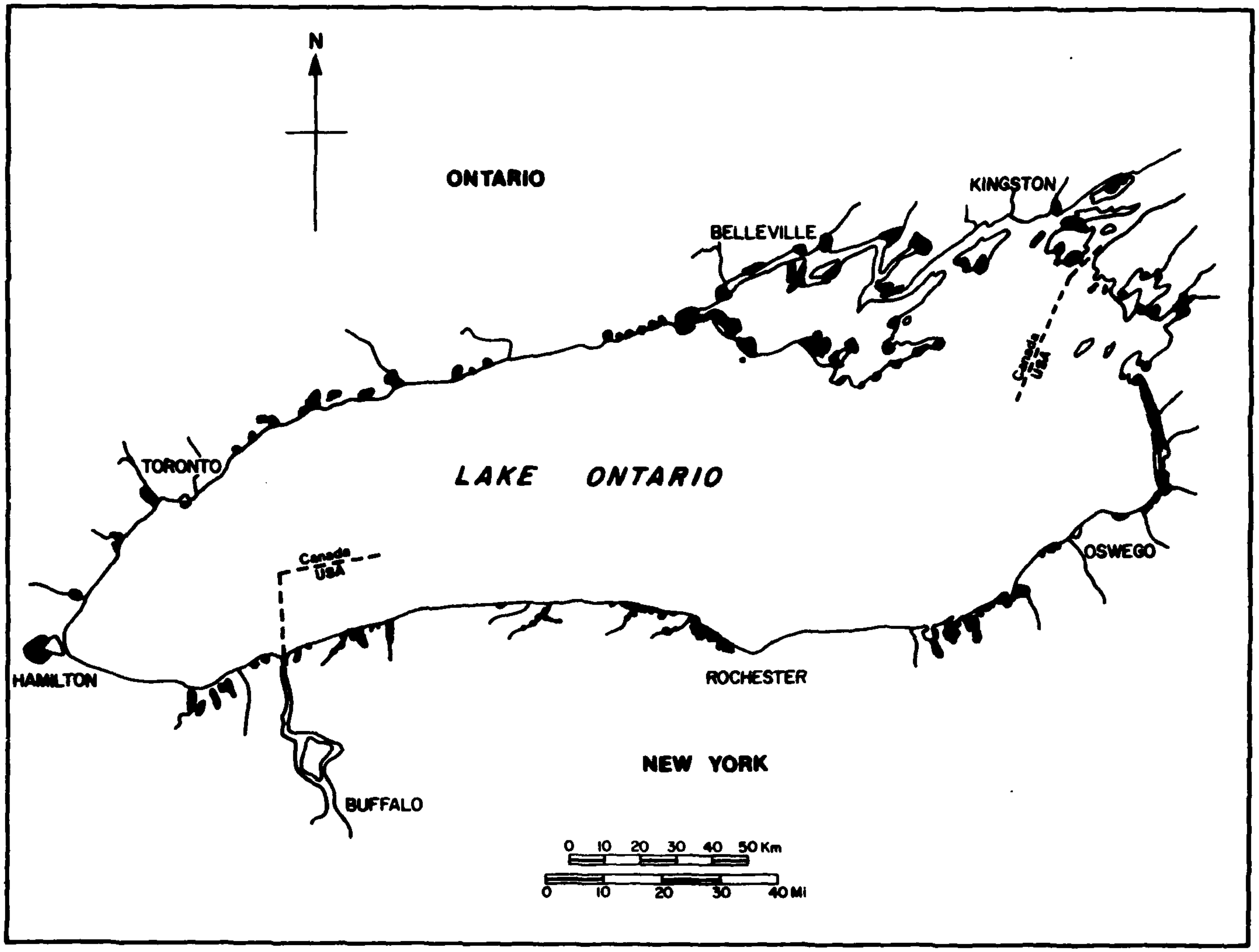

Figure F-25: Wetlands of Lake Ontario.

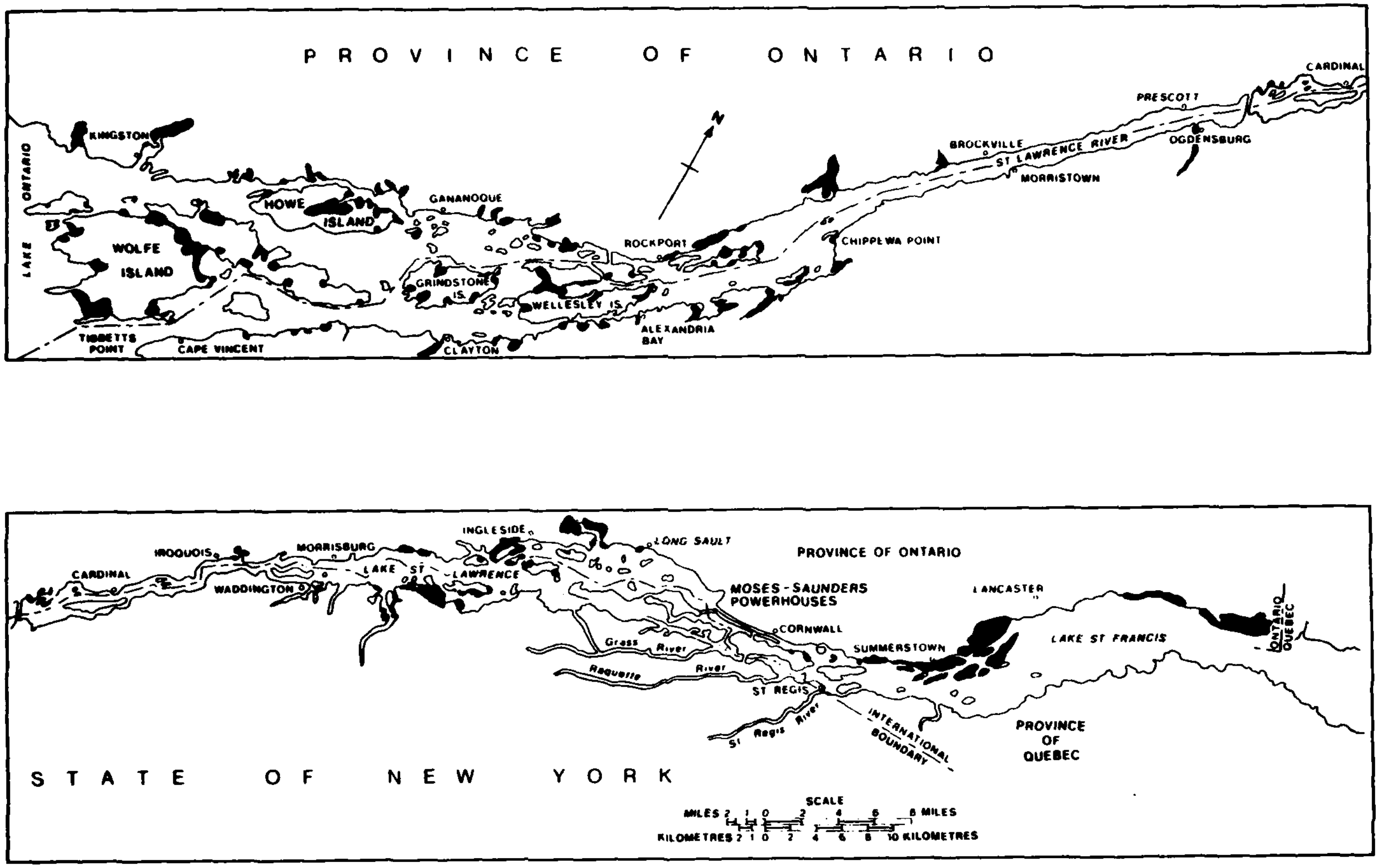

Figure F-26: Wetlands of the International Portion of the St. Lawrence River.

Wetland types were identified from air photographs, topographic sheets, or previous inventories. They were plotted on topographic maps and acreage were determined and documented according to water body and wetland type. The wetlands of the lower Lakes and the St. Lawrence River are shown as the darkened areas on the maps (Figures F-23 to F-26).

The productivity, biololgical composition, and size of the lower Great Lakes shoreline wetlands reflect the long-term water level regime. The regulation plans are expected to change long-term water levels that would be experienced under BOC, thereby also altering wetland conditions. This evaluation focused on those types of water level alterations which would have the potential to affect wetlands, such as: long-term annual mean; range of fluctuation; high water levels; low water levels; frequency and duration of high and low water levels; and, seasonal distribution (timing) of water.

For this study, all shoreline wetlands were considered to consist of four major vegetative zones. These zones shift position or change in size in response to the above-noted types of water level changes. The effects of the regulation plans were evaluated by predicting, on the basis of existing studies and professional judgement of biologists familiar with the Great Lakes wetlands, what types of zone shifts and alterations in vegetative composition could be induced by water level changes occurring under each plan.

The relative area which each of the four vegetative zones comprises in any wetland, affects its value for wildlife, fish, and other aquatic organisms. The effects of the regulation plans on wildlife were inferred by examining the zone changes in wetlands due to regulation. A listing of wetland dependent birds, mammals, reptiles and amphibians found in the Great Lakes area was also prepared and habitat preferences for these animals were determined (Annex 4).

In a recent study by Jaworski et al. (1979), information was provided concerning the responses of seven Great Lakes wetlands to recorded water level changes which might occur under regulation for two specific wetlands; one in Lake St. Clair and one in Lake Erie. Other information, although not as detailed, dealing with vegetative zone responses to altered lake levels for a few additional wetlands on Lakes St. Clair, Erie, and Ontario was provided by the Canadian Wildlife Service.

In assessing the systemic impacts of regulation, the following asumptions were made:

1. The existing Great Lakes shoreline wetlands have evolved in rsponse to water level regimes and environmental conditions, including man-induced changes.
2. The shoreline wetlands of the Great Lakes benefit biologically from, and require, fluctuating lake levels to maintain their productivity.

3. Future wetland conditions arising from a continuation of historic water regime patterns represent a zero change.
4. Wetlands classified as the same wetland type will react similarly to the same water level regime alteration.
5. Shoreline wetlands support aquatics-oriented wildlife, and any change in water level will have a more profound effect on that group than on terrestrial wildlife.

The effects of regulatory structures in the Niagara River and of remedial works in the St. Lawrence River were also examined. The structural evaluations focused on the effects of construction and operation or maintenance.

Shoreline wetlands exhibit plant community shifts in response to long-term lake level fluctuations. In general, low water conditions will produce an invasion of the sedge/meadow by shrubs, a displacement of emergents by the sedge/meadow, and a decrease in open-water and associated aquatics communities. High water conditions will produce an increase in open-water aquatics, as other communities decrease.

4.3 Existing Conditions

4.3.1 Value of Shoreline Wetlands

The values of shoreline wetlands to wildlife are variable and depend on a number of characteristics including, but not limited to, location, diversity of vegetation, size, water quality, gradation and soil. Some of the functions of wetlands include: nutrient cycling and settlement of sediments thereby enhancing water quality; storing ground water essential to biological, agricultural, domestic, and industrial needs; stabilizng surface waters during high flow periods to alleviate the danger of floods and erosion; providing aesthetic value in flora, fauna, and open space; providing recreational areas for hunting, fishing, birdwatching; and, providing breeding, nesting, feeding, resting and overwinter habitat for wetland dependent species of wildlife and fish.

Wetlands provide a habitat for a wide variety of wildlife, particularly fish, waterfowl, and furbearers. They are the major topographical feature on the lower Great Lakes shoreline that provide a good wildlife habitat (Martin et al. 1953, Bedford et al. 1976, Laidlaw 1978). Wetlands are essential to waterfowl that use them for migration staging, nesting and brood rearing. Of particular importance to waterfowl are the north and east shores of Lake St. Clair, western Lake Erie, the Long Point-Turkey Point marshes (central Lake Erie) and eastern Lake Ontario. These areas are utilized extensively by diving and dabbling ducks, partially because of the availability of such desirable food plants as sago pondweed and wild celery. Dabbling ducks, geese and swans are also attracted to the nearby harvested corn fields during migration (Dennis and Chandler 1974).

Wetlands contribute to the local economy. The fish, waterfowl, and furbearers provide the public with recreational opportunities such as hunting, fishing, and birdwatching. Wetlands also support economically important fur and fishing industries.

The wetland ecosystem, similar to any other association of plant communities, will, through succession, grow toward a climax state. Without periodic disturbances, wetland plant communities will shift to dense emergents and ultimately terrestrial vegetation. The climax state of wetlands does not, however, provide good quality habitat for wetland-dependent wildlife. Some water-level fluctuation and periodic flooding is necessary to set back plant succession and restore the more productive earlier stages.

Wetlands act as a buffer zone to the land, and are very efficient in their ability to absorb and dissipate wave action (Martin et al. 1953, Bedford et al. 1976, Laidlaw 1978). Coastal areas in the United States where marshes do not protect the shoreline, either because they never existed or were filled, require higher disaster relief allocations due to increased wave damage (Laidlaw 1978).

Wetlands enhance water quality by slowing waterflow and allowing suspended particles to settle (Lee et al. 1971, Bedford et al. 1976). The hydrology of a marsh is such that it tends to trap sediments which would otherwise settle in lakes or streams. Those accumulated sedimentary materials may physically trap nutrients and other chemicals detrimental to water quality while other nutrients and pollutants are tied up in plant growth.

Wetlands of the Great Lakes are exposed to variations in water levels caused by: long-term climatic cycles; short-term climatic occurrences; the annual distribution of water; seiches; and, wave actions. The present productive state of these wetlands has been attained in association wth these historic water-level fluctuations. Wetland communities will react to those water-level variations according to the pattern and magnitude of water-level changes, and the community tolerances to them.

The periodic disturbances, flooding and drying, interrupt plant succession to prevent the formation of dense beds of emergent vegetation, and to promote interspersion of vegetation and water; periodically release nutrients to the wetland, thereby promoting renewed plant vigor and increasing invertebrate populations essential to wetland wildlife; and promote species diversity, both of vegetation and wildlife.

4.3.2 Shoreline Wetland Classification and Inventory

An inventory of the lower Great Lakes shoreline wetlands was required to provide an accurate, up-to-date rsource base, upon which to base comments regarding effects of the regulation plans.

A wetland classification system was designed for the study. The study requires a classification that is specific for the Great Lakes

wetlands. Existing classification schemes (Millar 1976; Shaw and Fredine 1971; Jeglum et al. 1974; Cowardin et al. 1977) were not suitable for this particular study for various reasons. Millar's classification (1976) of western wetlands is not applicable, as it deals exclusively with prairie marshes. The U.S. Fish and Wildlife Service Circular 39 (Shaw and Fredine 1971) and a classification for Ontario wetlands (Jeglum et al. 1974), each includes the Great Lakes marshes, but are not detailed enough in typing the inland freshwater wetlands. The U.S. Fish and Wildlife Service wetland classification (Cowardin et al. 1977) is very detailed, but difficulties in interpreting size and wetland feature requisites for each system makes it impossible to use without more ground-truthing and field work.

Type definitions are based mainly on physiographic features due to a lack of published information of the biological characteristics of the Great Lakes wetlands that would be needed for a more in-depth classification.

Description of Wetland Types

Descriptions of the seven wetland types in the classification system are given below and illustrated in Fig. F-22. Each wetland type is described in terms of its physical and vegetational features. Examples of each type are also given:

1. Open shoreline wetlands usually exist as a hydrophytic vegetation fringe adjacent to the shore. That fringe can expand inland or lakeward in response to lake level changes but remains open fully to lake effects such as wave action.
   The dominant vegetation is usually emergent, but submergents can also be present, as this type can also include open-water areas of emergents and submergents that do not necessarily border on a shoreline.
   Examples of this wetland type are the north shore of the Inner Long Point Bay and sections of the Detroit River shoreline in the vincinity of Fighting Island.
2. Unrestricted bays are characterized by a marshy fringe along a bay shoreline, but these sites are afforded some protection from such lake effects as wave action. Depending on its size and depth, the wholebay could be vegetated. Submergents can be a part of those vegetative communities. This wetland type also includes typical open shoreline areas that are sheltered by an island or peninsula.
   Examples of this wetland type are the undiked section of the Ruhe Marsh on the Detroit River, and Bald Head Beach Marsh

(Wellers Bay) and Black River Bay on Lake Ontario.

3. Shallow sloping beach wetlands are areas with very gentle to almost flat slopes on sand substrates. Very small variations in lake levels may have widespread effects on vegetation zones. Sand bars, if present, may provide some wave protection.
   The large sand spit formations of Lake Erie, Long Point and Pointe aux Pins, constituted most of this wetland type.
4. River deltas are low islands and shallow zones formed by sedimentary deposits at a river mouth. The normally gentle slope allows the extensive shifting of vegetation zones when water levels fluctuate. The only wetlands identified as Type 4 are the large St. Clair River delta along the northern edge of Lake St. Clair and the mouth of the Salmon River on eastern Lake Ontario.
5. Restricted riverine wetlands are characterized by marsh vegetation bordering a river course. The extent of the vegetated wetland is often restricted by a steep backslope on the landward side and the deeper water of the river channel on the other. The Grand River Marshes, the Portage River Marshes and the Sandusky River Marshes of Lake Erie are examples of restricted riverine wetlands.
6. Lake-connected inland wetlands are typified by the presence of a barrier beach or ridge which restricts the outlet to the lake and also provides protection from wave action and other disturbances. Such wetlands can have a definite steep backslope or a gradual slope permitting some shifting of vegetation zones with changes in water regime. This type of wetland will have a connection to the lake, but a stream or ground discharge from its drainage basin, could contribute to its water supply.The Big Creek/Holiday Beach Marsh and Hillman Creek Marsh on Lake Erie, and Oshawa Second Marsh, Deer Creek Marsh and Sandy Creek Marsh on Lake Ontario are examples of this wetland type.
7. Protected wetlands include both diked wetlands, and ones separated from the lake by an unbroken natural barrier beach or ridge.
   The natural wetlands and some of the diked wetlands obtain their water from inland ground discharge, streams and at times from the lake, as when the wetland floods during storms. There is some seepage of water

through dikes, which extremes in lake levels can magnify.
The diked, managed wetlands of the eastern Lake St. Clair and western Lake Erie shoreline; Cranberry Marsh, Port Bay, Beaver Creek and Red Creek Marshes on Lake Ontario are examples of protected wetlands.

Wetland Inventory:

Wetlands in Canada were identified from 1971 and 1972 Ontario Ministry of Natural Resources aerial photographs (scale of 1:13,200), with the use of a pocket stereoscope. Wetland boundaries were then marked on 1:25,000 scale National Topographic System maps, of varying dates. Wetland mapping was standardized by basing it solely on the air photos because of inconsistency in the dates of the topographic maps, greater accuracy in defining wetland boundaries from air photos, and finally because the photo dates were more consistent. The upstream boundary, to which existing lake level fluctuations have an effect, was chosen arbitrarily based on either the amount of constriction in the basin and density of vegetation, or to the first major road.

Site specific studies provided gground-truthing at a few locations. Additional field trips were made to obtain information on the current status of some wetlands. Marshes just to the east of Toronto, and some in Prince Edward County were visited, and a flight was made over the extensive marshes of Lakes Erie and St. Clair to document wetland loss and change due to recent draining and diking.

All wetland areas were classified according to the seven wetland types. Wetland area was determined using a compensating-inch planimeter (polar planimeter). Three measurements were made for each wetland site and averaged.

The new baseline information on wetlands was catalogued. This included numbering the wetlands consecutively within each lake and interconnecting channel, and identifying the topographic sheet and air photographs on which the marshes were located. Usually a geographic name was given along with identification of the county and township. In addition to the site location, some observational characteristics were recorded in conjunction with the classification. These include bottom and backslope contours, which were defined as steep or gentle, and the nature on the hydrology (either dominantly lake or land supported). Also, predominance of emergent or submergent vegetation was noted.

An inventory was conductedon the U.S. side using available State and Federal wetlands data for the study area. Each State had inventories done at different times, hence, there are some differences in water levels at the time of inventory and identification procedures. There may also have been loss of wetlands since earlier inventories. A New York State inventory was done in 1969 (most of the photos were taken in 1967 and 1968). This was the oldest data used and follows a period of low lake levels. This inventory was compared wth U.S. Fish and Wildlife Service inventories completed in 1979

(Center for Lake Erie Area Research, CLEAR 1979) for major discrepancies. Where major dscrepancies were found, the wetlands were reevaluated with weight being placed on the most recent data.

The wetland area in Pennsylvania was limited to that area on and around Presque Isle. These data were taken from 1973 topographic maps. Ohio data were obtained from Land Use Maps dated 1977. Michigan data came from 1973 topographic maps which were updated from "Fish, Wildlife and Recreational Values of Michigan's Coastal Wetlands" by Jaworski and Raphael (1978). Lake Erie data were also updated with U.S. Fish and Wildlife Service inventories and corrected where major differences existed.

All U.S. wetlands were classified according to the seven types. Acreages, in this case, were determined by using a dot grid system (36 dots/sq.inch). The dots were counted twice and averaged. A sample of acreages obtained from the dot grid were compared with those using a polar planimeter and found to be comparable and the differences were within 10 percent.

Canadian and U.S. wetland areas were totaled by wetland type for each lake and interconnecting channel, (Table F-25).

4.3.3 Wildlife Resources

Wildlife is considered in .'o categories, those animals which are wetland dependent and those animals which are wetland utilizers (Annex 1 lists wildlife of the Great Lakes Region). Animals are considered wetland dependent if they need a wetland-type environment during some part of their life in order to survive. Animals which utilize the wetlands are those which are normally upland species, but which live in the area and use the wetlands for food, cover or water. Individuals of the latter group may spend their entire lives in the wetland, however, as a group they do not need this type of habitat for survival. Some species may not clearly fall into either category.

Emphasis in this report was on the wetland dependent animals. These species would be affected by subtle changes in this part of their environment. As previously stated, some other animals which use wetlands can survive without them. The deprivement of a portion of their environment, however, may substantially affect the animal's life processes.

Waterfowl:

Waterfowl from a numerical and economical standpoint is the most well known and most valuable wetland dependent species. Jaworski and Raphael (1978) state that $3,305,913 is contributed to the Michigan economy each year through waterfowl hunting alone. It is also estimated that at least 3 million waterfowl migrate annually through the Great Lakes region.

The Great Lakes shoreline wetlands are of primary importance as migration-staging habitat. Waterfowl from both the Atlantic and Mississippi Flyways funnel through the Great Lakes region. In particular, the wetlands of Lake St. Clair and lower Detroit River, western Lake Erie, Long Point

Table F-25

Wetland Area of the Lower Great Lakes by Wetland Type and Water Body Area in Hectares (Acres)

	1. Open Shoreline	2. Unrestricted Bay	3. Shallow Sloping Beach	4. River Delta	5. Restricted Riverine	6. Lake-Connected Inland	7. Protected	Total
ST. CLAIR RIVER								
Canada	221					15		236
United States								
Total	221					15		236
LAKE ST. CLAIR								
Canada	2,788			16,824	28		12,563	32,203
United States	125			5,848	56	298	3,805	10,132
Total	2,913			22,672	84	298	16,368	42,335
DETROIT RIVER								
Canada	600	123			98		633	1,454
United States	125	135						260
Total	725	258			98		633	1,714
LAKE ERIE								
Canada	516	141	18,195		2,313	5,221	2,637	29,023
United States	2,005	1,618	374		1,569	510	18,236	24,312
Total	2,521	1,759	18,569		3,882	5,731	20,873	53,335
NIAGARA RIVER								
Canada								
United States	57	12				197	26	292
Total	57	12				197	26	292
LAKE ONTARIO								
Canada	1,114	6,353	534		6,035	4,484	590	19,110
United States	280	1,721		90	919	4,401	5,901	13,312
Total	1,394	8,074	534	90	6,954	8,885	6,491	32,422
ST. LAWRENCE RIVER								
Canada (Ont.)	6,910	3,965			1,917	1,333	23	14,148
United States	1,029	1,357			1,609	2,828	455	7,278
Total	7,939	5,322			3,526	4,161	478	21,426
TOTALS								
Canada	12,149	10,582	18,729	16,824	10,391	11,053	16,446	96,174
United States	3,621	4,843	374	5,938	4,153	8,234	28,423	55,586
Total	15,770	15,425	19,103	22,762	14,544	19,287	44,869	151,760

(Central Lake Erie) and eastern Lake Ontario receive intensive use. The vital Lake St. Clair marshes are centrally situated and waterfowl migrating along both the Lake Huron and Lake Erie shorelines tend to funnel into this area (Dennis and Chandler 1974).

The marshes of Lakes Erie, St. Clair and Huron are used by about two-thirds of the North American population of Whistling Swan. The eastern continental populations of Canvasback and Redhead Ducks depend on the wetlands and associated open-water areas of the lower Great Lakes during migration periods. Wetland areas, other than those noted above, receive less intensive use, but are still of regional importance. Waterfowl survey data for the Canadian wetlands of the lower Great Lakes illustrating the importance of these shoreline as migration-staging habitat are presented by Dennis and Chandler (1974).

Wetlands provide a variety of quality habitats attractive to staging flocks of geese and dabbling and diving ducks. This is partly because many of these marshes are managed solely for waterfowl and muskrats. Some have sanctuary areas where birds can feed or rest undisturbed. These usually are attractive natural marsh bays that support excellent growths of important submergents such as wild celery and sago pondweed.

"Legal baited areas" present in many of the Canadian marshes, provide additional sanctuaries to attract geese and dabbling ducks. Adjacent inland cornfields supplement the baited aeas and help to hold field-feeding birds in the area for a longer period (Dennis and Chandler 19o74). The undiked Detroit River marshes have another specific advantage that holds birds; the river currents and moderate climate keep the water open later into the autumn and break the ice up earlier in the spring.

The Great Lakes wetlands are also utilized by waterfowl for nesting, but this tends to be of local importance. Nesting generally begins in April for most species and extends through June. Water levels at this time are rising or have reached their high annual stages. Nesting sites for most ducks are within 100 meters of water, with some species (e.g., Redhead) preferring emergent vegetation, and other species (e.g., Mallard and Blue-winged Teal) preferring upland areas.

Foods of waterfowl vary considerably among species and also between age classes of the same species. Both plant and animal matter (insects, crustaceans and mollusks) are important food sources. Plant species used as food are quite diverse, and their use depends on availability. Table F-26 lists some common marsh plants found along the Great Lakes and their use by waterfowl. Waterfowl will also utilize harvested corn and grain fields in the vicinity of the wetlands.

Herons, Rails, Coots, Grebes and Gallinules:

Four species of herons (the great blue, little blue, green and black-crowned night heron) inhabit the Great Lakes area (Martin et al. 1961). The American and least bitterns and the common egret, cattle egret, and snowy egret are also found in the marshlands along the Great Lakes These birds feed on fish, amphibians, crustaceans, insects and small mammals.

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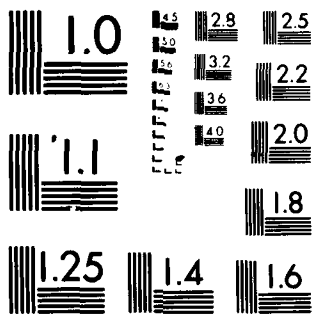

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Table F-26

Common Waterfowl Food Plants of the Great Lakes Region
(adapted from Martin et al. 1961)

Common Waterfowl Food Plants of the Great Lakes Region
(adapted from Martin et. al. 1961)

Pondweeds (Potamogeton sp.) - Primary vegetation used as food by many waterfowl species in the Great Lakes Region.

Algae - Certain types of algae provide food for ducks (Musk grass) and also provide habitat for aquatic insects and other invertebrates which are eaten by waterfowl.

Naidas - Good duck food in Eastern U.S.

Arrowheads (Sagittaria sp.) - Tubers of duck potato used by some waterfowl.

Wild celery (Valisineria americana) - Important duck food especially for diving ducks.

Rice cut-grass (Leersia oryzoides) - Utilized by ducks but not a preferred food.

Wild rice (Zizania sp.) - Important duck food for most ducks when available.

Wild millet (Echinochloa sp.) - Good food for waterfowl, introduced in some areas.

Chufa (Cyperus sp.) - Provides a food surce for some waterfowl, both seeds and tubers are utilized.

Bulrush (Scirpus sp.) - Important and commonly used food of ducks, also serves as nesting cover.

Arrow arum (Peltundda sp.) - Large berries are relished by wood ducks.

Duckweeds (Lemna sp.) - Utilized by ducks in summer and early fall, many invertebrates associated with it.

Smartweed (Polygonum sp.) - A few species are important food producers, especially as water recedes and seeds are dropped.

Coontail (Ceratophyllum demersum) - Submergent, abundant but not used for food extensively.

Rails, coots, grebes and gallinules are also marsh birds found commonly in the Great Lakes region. These birds are omnivorous in their food habits but feed largely on animal matter (insects and crustaceans). Favorite plant foods eaten by these birds include wild rice, sedge and bullrush. Nests are built in the dense vegetation of marshes from a few inches to 3 or 4 feet above the water depending on the species.

The sora and Virginia rail are similar in nesting habits, with the sora rail preferring the drier areas at the water's edge, and the Virginia rail nesting in the emergent vegetation over the water (Weller and Spatcher 1965). The Virginia rails breeding on the Great Lakes are species specific for nesting cover with nests being almost exclusively found in cattail (McCracken 1978).

Coots, least bitterns, common gallinules and pied-billed grebes are similar in habitat requirements. Coots and gallinules only nest in emergent vegetation, which allows them to swim to and from the nest. The pied-billed grebe prefers evenless dense emergent vegetation and considerably more water interspersion. High water levels open up more areas to these birds as vegetation is flooded, with lower levels tending to reduce the amount of suitable habitat (Bent 1963a, Weller and Spatcher 1965, Weller and Fredrickson 1973).

Shorebirds:

Four species of plovers are found along the shores of the Great lakes; the Piping plover, however, is the only one reported nesting in this area (Jurek and Leach 1977). Their food consists principally of insects, worms, crustaceans and mollusks which are gathered along the lake shores. The killdeer is also a plover and quite common throughout the region, but more often found in the upland areas. Plovers nest on the ground; the Piping plover, generally along shore among rocks.

The sandpipers comprise a large and diverse group of shorebirds. A number of species are found along the Great Lakes, however, only two (Upland and Spotted sandpipers) are reported to nest in th area. Sandpipers nest on the ground, generally near water. Their major food items are crustaceans, mollusks, worms and insects.

The phalaropes are similar to the sandpipers, but are primarily ocean feeding birds and seen only on rare occasions in the Great Lakes area as they migrate through. The American avocet may also be seen during migration from breeding areas to the sea. These birds feed on insects, crustaceans and other small aquatic fauna.

Gulls and Terns:

Another important group of birds utilizing the shoreline wetlands are the non-resident gulls and terns. As previously noted, the black tern nests in the marsh but the majority of this group of birds nest in colonies on beaches, sandspits, or low barren islands (Blokpoel 1977, Blokpoel and McKeating 1978). Such colonies are often adjacent or in close proximity to wetlands and the birds periodically utilize the marshes as feeding areas (Bent 1963b). The wetlands support fish, invertebrates, and insects which these birds either catch live or scavenge. High water levels would generally have a detrimental effect on these birds due to loss of nesting habitat, conversely, low water levels would be beneficial.

Other Birds Associated with Wetland Habitats of the Great Lakes:

Other birds are associated with wetland and setland-edge habitats during some time of their life cycle. This large and diverse group includes: eagles, marsh hawks, osprey, swallows, marsh wrens, warblers, blackbirds and sparrows.

The bald eagle is on the United States list of threatened and endangered species. These birds nest in trees usually near water. The main food item is fish either taken alive or scavenged.

The osprey is also listed by some states as threatened or endangered. These birds also nest in trees or on platforms. The main diet of the osprey is fish usually taken alive. The marsh hawk is usually found in marshes but is not as dependent on water habitats as the osprey or eagle.

There are many species of swallows, wrens, sparrows, warblers and blackbirds which are wetland dependent. Most of these birds nest in the dense vegetation such as cattails, shrubs or sedges; or in banks or structures along the water's edge. Food items are mainly insects, seeds and small invertebrates.

Reptiles and Amphibians:

This group of animals consists of reptiles (snakes, lizards and turtles) and amphibians (frogs, toads and salamanders). Amphibians are all dependent on water or wetland habitats. Water habitats are necessary for both the egg and larval stages of these animals. Some s[illegible] spend their adult stages on land, but still generally require moist c[illegible]ons.

The reptiles are, as a group, more terrestrial than amphibians; however, some species such as those mentioned in Annex 4 rely heavily on shoreline habitats.

Habitat requirements for reptiles and amphibians are varied; however, the riparian species are generally found in shallow areas or well vegetated fringes of marshes. Many species spend the winter in mud or sand in the bottoms of ponds or marshes. All must evade the extreme

low temperatures experienced above ground. Some mortality would be experienced when freezing conditions penetrate to the depths of the hibernating animals, e.g., low water levels during winter months.

Mammals:

Some species of wetland-dependent mammals that inhabit the shores of the Great Lakes may be influenced by the changing water level. Most noticeable are the furbearers such as muskrat, beaver and otter. Many other mammals live near the lake shore wetlands and use these wetlands for food or cover but may not be "dependent" on these areas for survival.

Habitat quality and availability, controlled by water level fluctuations, are primary factors regulating muskrat populations (Friend et al. 1964, Weller and Spatcher 1965, and Weller and Fredrickson 1973) indicate that muskrats were more abundant initially in their study area as the marsh was flooded by high water levels, but that they would decline due to the decay of necessary emergent vegetation. The most important vegetation for muskrats is cattail. Cattail is the major food species and cover plant as well as lodge building material (Errington 1963).

Muskrats are economically important. It is estimated from the Ontario Ministry of Natural Resources' Harvest Records that 25 percent of the total muskrat harvest for the Province of Ontario is taken from shoreline wetlands of the lower Great Lakes. For the 1978-79 harvest, this represents 116,000 muskrats with a fur value of about $818,000.

Major fluctuations in water levels can be damaging to muskrat populations. Sudden water level increases, such as those generated by wind tides, can be very harmful by uprooting emergent beds, flooding out muskrat houses and generally disturbing populations. Areas with continually rough, wave-swept water are not dense enough in vegetation to be considered significant habitat. These disturbances reduce the areas of possible good muskrat habitat in the wetlands and creeks adjacent to the Great Lakes. In low water regimes during the winter, when bottom feed beds or the approaches to them freeze, muskrats are unable to gain access to food supplies (Errington 1963, Friend et al. 1964). Summer reductions in the water levels allow emergents to invade a larger water area, thereby increasing the amount of habitat available when reflooding occurs. Relatively stable hemi-marsh conditions are the most favorable for muskrat populations.

Beaver can also be found along some small bays and streams of the study area. Food usually consists of woody vegetation such as aspen, willow or birch.

River otter may use some of the more remote wetlands within the study area. Their numbers are quite limited. Their food consists of animal matter; fish, crayfish, frogs and some insects. The otter lives in a den usually along streambanks and is always near water.

4.4 Water Levels And Wetlands - General Overview

The existing Great Lakes shoreline wetlands have evolved in response to past water level fluctuations and environmental changes specifically those in the last 20 years. Changes in the timing and duration of water levels results in changes in the vegetative composition and/or areas of the shoreline wetlands and ultimately in wildlife utilization. Geis (1979) described some of the processes associated with wetland distribution. He stated that "...water levels represent the single most important variable in defining the extent, species composition, and stability of coastal wwetlands along Lake Ontario and St. Lawrence River."

4.4.1 Soils and Turbidity

Soils in the Great Lakes wetlands vary in fertility, depth, texture, erodibility, consistency and type. Water levels affect the soil fertility in several ways: nutrients are carried by currents and wave action and deposited in bottom soils, which is pronounced in river deltas where there is a considerable current entering a calm area; and, nutrients are lost from the soil when the water recedes after flooding and oxidation occurs. These changes in the soil conditions affect plant species, distribution and abundance in the marsh.

Changes in water transparency would have the greatest effects on submergents, since these plants require light penetration. Transparency is dependent upon the amount of suspended material in the water. Rain storms, changes in currents, wind and wave action, aquatic animals (carp), farming practices and land use are contributors to transparency changes.

4.4.2 Vegetation

Plants are primary producers and affect all other wetland organisms either directly as food and cover or indirectly by attracting prey for the carnivores. Certain vegetation types are limited by water depths. Bellrose (1941) indicates that emergent marsh plants do well in moist soil or water less than 45 cm (18") deep while submerged aquatic plants do best in water 45 to 122 cm (18" to 4'). Geis and Kee (1977) state "... major changes in life form composition occur at a depth of 50-60 cm (19" to 23") where emergent species replace submerged aquatic, and at about 10 cm (4") where woody shrubs become prominent ".

Weller (1978) states that "...manipulation to produce early plant successional stages results in longer lasting benefits, and creates diverse habitat niches". The high levels move the wetland inland and kill much of the existing emergent vegetation, as the water recedes and exposes the bottom soil regeneration of the vegetation takes place.

An unflooded marsh usually has cattail surrounded by rushes and other weeds and grasses. After flooding there would be an invasion of submergents, floating vegetation and emergents with the latter showing the most rapid invasion rate (Dane 1959). Flooding produces a larger and

more diverse marsh by precluding the formation of dense senescent vegetation and also enables the wetland to export-organic or fne-grained sediment within the wetland.

The timing and degree of seasonal water-level fluctuations are very important to vegetative growth (Weller 1978). Winter water levels are very critical to some wetland communities. The high levels in the winter of 1972-73 in Lake Ontario caused large die-offs of vegetation, particularly cattail. Overwinter drawdowns stimulate greater growth emergent vegetation following early spring germination. If water levels then increase until summer or early fall a well-balanced interspersion of emergents and open water should occur.

In early spring, as water levels rise, the ice breaks up and dislodges roots, rhizomes, etc., of the vegetation. If water levels are low an ice foot will migrate lakeward affecting a larger area. Both abnormally high and low winter levels "...increase the degree of natural habitat disruption that occurs during spring breakup through increased edge break-off and bottom lifting" (Geis, 1979).

Vegetative Changes in Wetland Types:

Each wetland is unique, however, due to changing water levels the following general vegetative changes would occur in the different Wetland types. The predictions are based on professional opinions and not on scientific studies.

1. Open Shoreline

   A lowering of the lake level would result in a corresponding shift of the vegetative fringe. The amount of lakeward shift depends on the bottom slope. A shoreward zone of vegetation would be left dry. The lakeward shift of vegetation would terminate wherever the water becomes too deep for rooted plants to survive or the substrate is unsuitable.
   When the lake level rises, there would be a shoreward shift of the vegetational fringe. Die-offs would occur in water that has become too deep, but that could be offset to some degree by pioneering vegetation on the inshore side of the old fringe that has become inundated. If the backslope is too steep, high-water levels could eradicate emergents in open-shoreline wetlands.

2. Unrestricted Bay

   Water-level changes would have effects on this wetland type similar to those described under "open-shorelines". If, however, the wetland is located in an already shallow bay, a lowering of water levels could create a condition encouraging dense emergent growth.
   A rise in the lake level would thin out intolerant

vegetation, and, if the backslope of the site were gentle, there would be inshore establishment of pioneer vegetation. If the backslope were steep and the water level too high, there would be no inland pioneering and the vegetation could be eliminated.

3. Shallow-sloping Beach

A lowering of lake levels would produce extensive areas of dense emergents in this wetland type. At extreme low levels, large sections of completely dry substrate would be evident.
High lake levels would tend to produce a more open wetland. Vegetation that cannot adapt would die off. Plant associations would change, with much of the area supporting extensive beds of submergents and floating-leaved aquatics. Because of the gentle slope of the land form, slight fluctuations would result in vegetative shifts over large areas.

4. River Delta

Low water levels could cause a lakeward shift of vegetation zones, while higher water levels could shift vegetation zones landward. Diking to manage wetlands has increased during low water periods (e.g., Walpole Island Delta). Diking will prevent the natural shifting of vegetation zones over much of the wetland. Many of the remaining undiked areas have a steep backslope (dikeface), and, therefore, vegetation zones cannot shift landward, although the lakeward shifting of vegetation is still possible.

5. Restricted Riverine

Spring flooding occurs more on riverine wetlands than others. These wetlands are partially or wholly protected from lake disturbances, but spring and early summer flooding may be intensified by high lake levels. Greater interspersion of vegetation and open water would result. With lower lake levels, the wetlands would tend to a drier state during summer and fall except during short term rises in the river levels.

6. Lake-connected Inland

Because they tend to be situated in bowl-shaped basins, lake-connected inland wetlands tend to develop toward a more "closed state" during extended periods of low water. The presence of a barrier beach would prevent the lakeward shifting of the wetland and there would then be a greater dominance by emergent vegetation, especially in a marsh with no feeder stream. If the outlet to the lake

closed because of lower lake levels, stagnation might increase due to the reduced water circulation.
High lake levels may eliminate all or a good portion of the emergent vegetation if the wetland backslope is steep or the water increase extreme. In instances with more gentle wetland backslope and a less severe increase in water level a more typical shift of vegetation zones should occur.

7. Protected Wetlands

Lower lake levels would lead to lower water levels in the naturally protected marshes, encouraging denser emergent growth. In the diked marshes, lower lake levels would necessitate more pumping to alleviate effects, and thereby increase management costs to the owners.
High lake levels would produce high water levels in both the natural and diked marshes due to seepage from the water pressure differential on the dike. Overtopping of dikes and barrier beaches during storms would cause increased flooding. During high water years managed diked marshes would require less pumping time to maintain water levels conducive to productive interspersion of vegetation and open water. But, extreme high levels could result in breaching of dikes and costly repairs.

In general, wetlands with more protection from lake effects, in the form of barrier beaches or sand bars, are prevented from shifting lakeward with lower lake levels. The vegetative communities would tend to shift from hydric toward mesic conditions.

For this study, all shoreline wetlands as on Table F-27 are considered to consist of four major vegetative zones. These zones shift position or change in size in response to water level changes. The relative area which each of the four vegetative zones comprises in any wetland, affect its value for wildlife, fish, and other aquatic organisms.

4.4.3 Wildlife

Weller and Spatcher (1965), Weller and Fredrickson (1973), and Murkin (1979), describe optimum wetland wildlife habitat as a hemi-marsh, i.e., 50 percent open water and 50 percent wetland vegetation. The hemi-marsh condition produces the greatest habitat diversity for wetland-dependent wildlife species. Weller and Spatcher (1965) working in an inland Iowa marsh, correlated the changes in marsh cover - water ratios, and vegetation density to bird population dynamics. They concluded that the hemi-marsh was the most productive successional stage of wetlands for marsh birds (see Table F-28).

Table F-27

Vegetative Zones of Wetlands and Typical Plants Associated with Each Zone

Zones	Plants	
open water/floating-leaved/submergent:	pondweeds	*Potamogeton* sp.
	coontail	*Ceratophylum demersum*
	milfoil	*Myriophyllum* sp.
	waterweed	*Elodea canadensis*
	duckweed	*Lemna* sp.
emergent:	cattail	*Typha* sp.
	bulrush	*Scirpus* sp.
	arrowhead	*Saggitaria* sp.
	spike-rush	*Eleocharis* sp.
	burreed	*Sparganium* sp.
sedge/meadow:	sedge	*Carex* sp.
	beggar tick	*Bidens* sp.
	canary grass	*Phalaris* sp.
	bluejoint	*Calamagrostis* sp.
shrub/tree:	willow	*Salix* sp.
	dogwood	*Cornus* sp.
	sweetgale	*Myrica* sp.
	alder	*Alnus* sp.

Table F-28

Stages of the typical habitat cycle in semipermanent marshes (from Weller and spatcher 1965)

	Stage Name	Water in relation to *basin capicity*	*Vegetation*	Muskrat *Populations*	Bird *Populations*	Conspicuous indicator conditions
A.	Dry Marsh	Absent of low: emergents dry or nearly dry at base	Dense revegetation most species find a suitable seed bed	Low to absent, populations centrally located	Redwing sparse some use by upland birds	Redwings, few muskrat lodges
B.	Dense Marsh more vegetation than open water	Increasing water levels: emergents flooded	Very dense: rate of opening dependent upon muskrat populations and influences of *flooding on* certain species	Increasing	Numbers and variety increasing	Redwings increase Yellowhead adjacent to sparse open pools, few coots and gebes
C.	Hemi-Marsh Open water and vegetation equal	Median to near maximum	Muskrat eat-out, floatations and death: decline in shallow water species: deep water species	Increasing rapidly: well distributed	Maximum species diversity and production for most species	Many redwings, Yellowheads uniformly distributed: coots and pie-billed grebes abundant
D.	Open Marsh more water than vegetation	Maximum	Submergents and deep water species persist: others gone or going	Maximum or declining	Most species declining, a few swimming species liberate as long as some vegetation persists	Sparse bird populations and emergents
E.	Open Water Marsh vitually an eutrophic lake	Maximum or as low as median	Handstem bulrush may persist in sparse popula- tions	Sparse, bank dens common	Redwing use shoreline ve., Other species virtually absent except as migrants	Redwings use shoreline shrubs and trees

In Lakes St. Clair and Erie area, during the most recent high water period, the shoreline marshes suffered emergent vegetation die-backs and reverted to more open water. Following receding water levels, many vegetative communities reestablished themselves (Raphael et al. 1978). There has been effective recolonization of some plants such as sedges but not as yet by others such as cattail. It should be noted that neither flooded nor dry marshes are by themselves most suitable for wildlife. Combining these changes over a period of time, however, seems to maintain the most desirable conditions. Kadlec (1962) states that "...although these (water level) fluctuations are sometimes the subject of considerable concern, they are probably important in maintaining the productivity of the marshes...". Fig. F-27 depicts a typical wetland habitat and the habitat selection of various wildlife species in the wetland.

Water level fluctuations comparable to recent historical conditions (i.e., last 20 years) are required to maintain the long-term productivity and diversity of the wetlands. High water conditions (i.e., levels above the historical long-term mean) produce habitat conditions approaching the hemi-marsh which benefits wildlife such as waterfowl, muskrats, black terns and herons. These conditions increase wildlife species diversity, "... provide improved habitat conditions for invertebrates, amphibians, and reptiles...". High water may facilitate the interchange bewtween the lake and wetland, and thus permit fish spawning (e.g.,northern pike) as well as the wetland rearing of forage fish (Jaworski et al. 1979).

Low water conditions (i.e., water levels below the historical long-term mean) encourage the predominance of the sedge/meadow and dense emergent zones. During extended low water years, wildlife species diversity decreases with habitat conditions favoring red-winged blackbirds, short-billed marsh wrens, rails, white-tailed deer, cottontail rabbits and small rodents.

The short-term (less than 4 years) effects on waterfowl and marsh birds due to extreme high water levels are generally considered to be detrimental. Bednarik (1969) states the high water levels result in concentration of nests on dikes where they are subject to high rates of predation or destruction by flooding. The reduction in area of suitable habitat also would provoke some stress among the individuals, e.g., competition for space and territoriality.

Waterfowl are especially sensitive to seasonal water level fluctuations during breeding periods. To minimize incidences of nest flooding, stable water levels would be desirable during the spring and early summer (Bedford et al. 1976). During July and early August the normal gradual drop in water levels can expose beds of pondweeds and smartweed increasing growth (Kadlec 1962, Linde 1969, Bedford et al. 1976). In late August, if water levels rise again due to precipitation or other causes, the resultant flooding of these food plants will make the area very attractive to waterfowl. The normal water level fuctuations in the Great Lakes differ somewhat from this sequence. There is an increase in levels in the spring and early summer with the highest

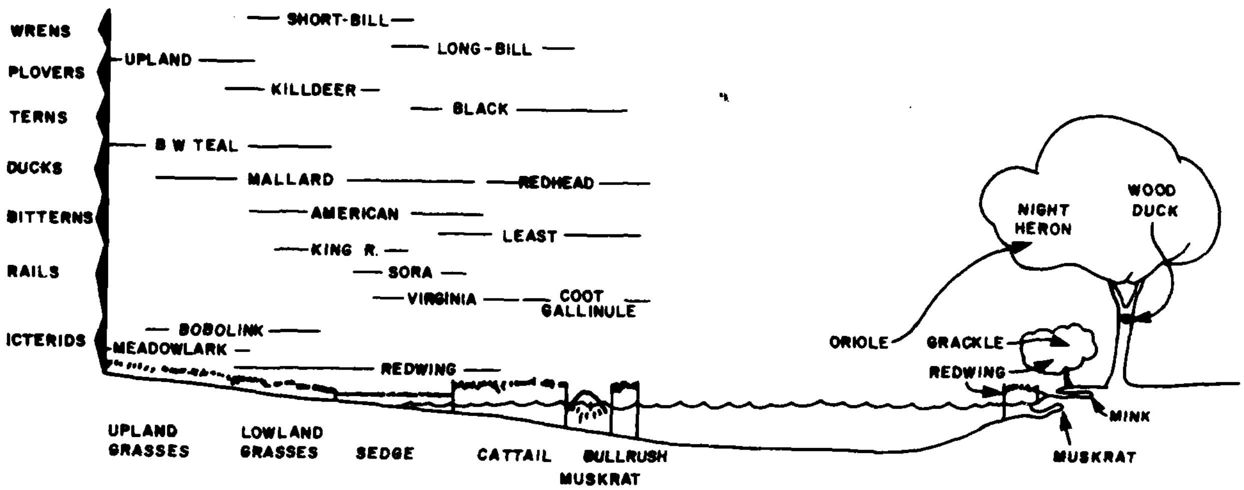


Figure F-27: A schematic drawing of the habitat selection by several species of resident and breeding wetland-wildlife. (From Weller and Spatcher 1965)

levels generally being achieved during summer (June to September). After this there is a steady drop until winter or early spring (Nov.-March) when the upward cycle begins again. Fluctuations are needed to maintain productivity and control vegetation so the habitat will remain suitable for the waterfowl and other marsh co-inhabitants (Munro 1965, Linde 1969).

4.4.4 Vegetative Zones and Wildlife Use

The relative area which each of the four vegetative zones (i.e., open water/floating-leaved/submergents; emergent; sedge/meadow; shrub/tree) comprised in any wetland, affect its value for wildlife.

The greatest diversity and abundance of wetland-dependent animal species occurs in the interspersed open-water aquatics and emergent zones. The least species diversity occurs in the sedge/meadow zone. McCracken (1978), working in the Big Creek National Wildlife Area, found a much lower density and diversity of bird species in a study area that was dominated by bluejoint and sedge, and supported little if any cattail. Swamp sparrows and yellow-throats favored that dry area dominated by grasses. Conversely, the area was "...unsuitable for such water-loving birds as gallinules, coots, grebes, terns and waterfowl..." (McCracken, 1978).

McCracken et al. (1980) discussed five marsh zones with reference to breeding birds. High species diversity and density were noted in the wet grassy marsh (which the authors state corresponds to Weller and Spatcher's hemi-marsh), whereas the dense cattail marsh and the dry grassy marsh-shrub carr (dry) zones were characterized by relatively low levels of species diversity and density. The authors noted that from 1978 to 1979 falling lake levels reduced the water cover in the marsh zones and created denser vegetation. Breeding-bird surveys indicated that the populations of species that require areas of open water generally declined in 1979, and that populations of the more terrestrial passerine species generally increased as the marsh became drier and the vegetation more dense.

The sedge/meadow zone forms an important part of the wetland ecosystem, but an increase in area of that zone at the expense of interspersed emergents and open-water aquatics drastically reduces the wildlife diversity of a wetland.

Figure F-28 illustrates that the greatest diversity of waterfowl, birds and muskrats occurs at or slightly above the 50/50 ratio of open water to vegetation. At low water, or dry conditions, only a few species increase in abundance, whereas the abundance of most wetland dependent species declines rapidly. Table F-29 illustrates the change in wildlife use and other wetland functions at low and high water levels.

4.5 Evaluation of Regulation Plans

In the evaluation, expected wetlands under regulation were compared with the wetlands as they are likely to exist under the BOC water level regime. The following explanation of the systemic effects of lake level regulation focuses initially on the general manner in which

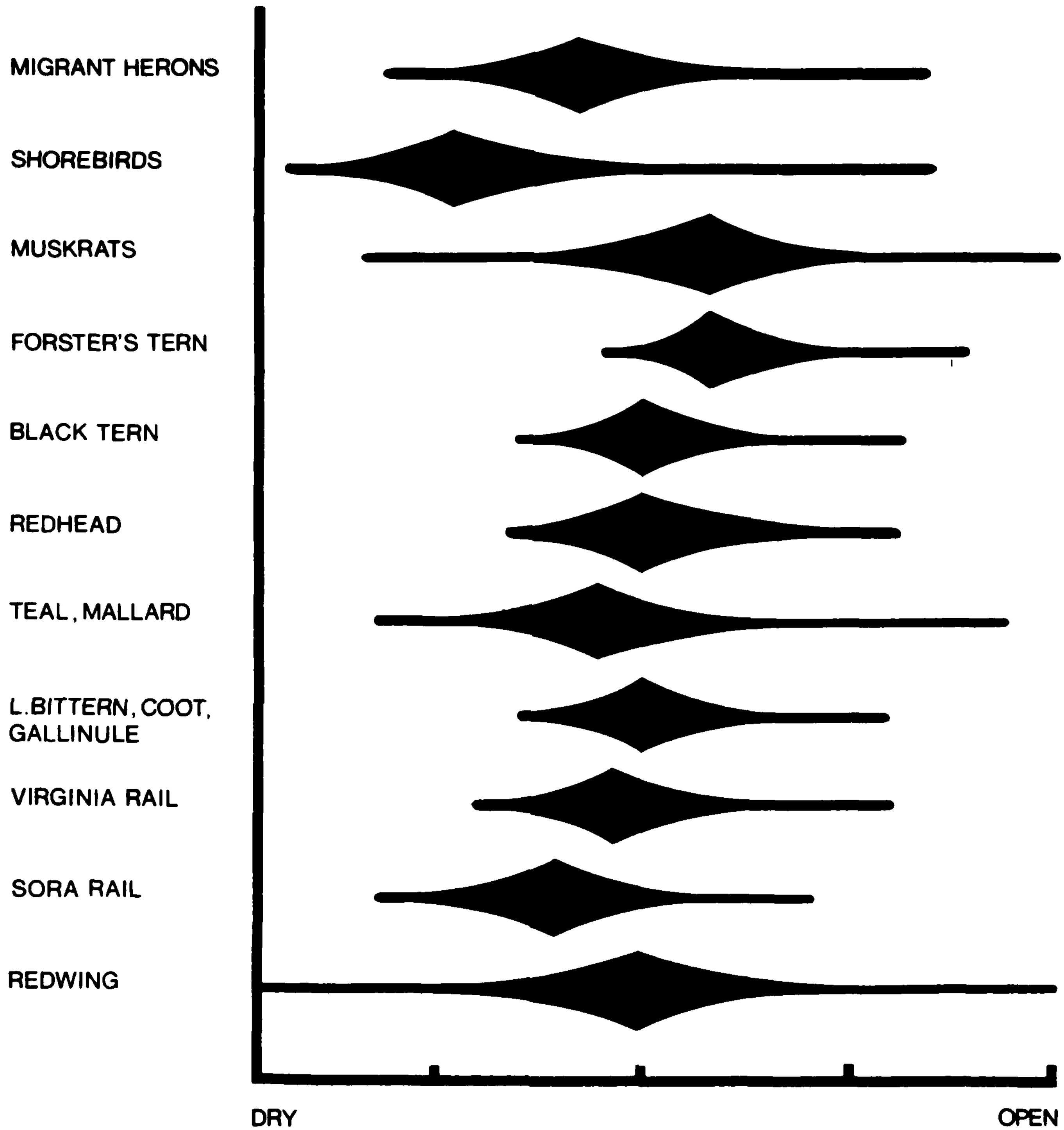


Figure F-28: Scematic presentation of the change in abundance of marsh birds in relation to the extremes in habitat conditions of semi-permanent marshes. (From Weller and Spatcher, 1965.)

Table F-29

Wildlife Use and Other Functions of Coastal Wetlands
at Low and High Water Levels. (Modified from Jaworski et al. 1979)

```
    Use/Function of Wetlands            Low Water                High Water

A.  Use by Wildlife:

    Blue-winged teal (breeding)         - - - ---------
    Red winged blackbird                ----------- - - -
    Mallard (breeding)                  - - ------------------ - - -
    Short billed wren                   ---------- - -
    Muskrat                             - - - ---------------- - - -
    Black tern                                                     - - -----------
    Yellowheaded blackbird                                         - - -----------
    Great blue heron                             - - - - --------------------
    Belted kingfisher                            - - - - --------------------
    Crayfish                                     - - - - --------------------
    Frogs and turtles                                - - --------------------
    Dabbling ducks (feeding)            -- - - --------------------- - - - -

B.  Other Functions:

    Hemi-marsh                                          - - - --------------
    Dominance of land drainage          --------- - -
```

the vegetative composition of the shoreline wetlands changes relative to the water level parameters listed in the methodology section. General response of the wetland types to water level alterations of the order of magnitude of the regulation plans are also discussed. The comments are directed primarily at the wetlands of Lakes Erie and St. Clair, with some discussion of Lake Ontario and the St. Lawrence River. Finally, effects of vegetation zone shifts on wildlife are reviewed.

4.5.1 General Effects of Water-level Changes

The productivity, biological composition, and size of the lower Great Lakes shoreline wetlands are reflection of the long-term water level regime. The regulation plans are expected to change long-term water levels thereby altering wetland conditions. This evaluation focuses on those types of water level alterations which would have the potential to affect wetlands. These would be changes in: long-term annual mean; range of fluctuation; high water levels; low water levels; frequency and duration of high and low water levels; and, seasonal distribution (timing) of water.

Effects of regulation plans on wetlands are discussed below with respect to changes in the above noted hydrologic parameters.

Lake St. Clair and Lake Erie:

The regulation plans would reduce mean water level. In general, a wetland would exhibit more mesophytic vegetative characteristics as a result of a lowerted mean water level. Sections of a wetland that contain interspersed open-water aquatic and emergents would experience low water levels for longer periods of time, which would encourage the establishment of dense stands of emergents and sedge/meadows at the expense of open-water aquatics.

A reduced range of water-level fluctuation would result in a reduced wetland area. On the landward edge of a wetland, there would be a zone that was periodicallly inundated under natural conditions that would no longer be inundated with the regulation plans in effect. The size of the zone would be dependent upon the bottom contour and backslope of the wetland, and the regulation plan.

A smaller range of fluctuation of lake levels would encourage a more dense growth of emergent vegetation. This condition would result in less drying out and flooding and thereby encourage less diverse wetland communities.

All regulation plans would result in a lowering of maximum levels. This change would, over a period of time, result in a loss of wetland area along the landward edge of the wetlands. There could be a lakeward shift in vegetation zones and a general loss in open water/submergents.

The minimum levels would be lowered slightly, which would add to the mesophytic characteristics of the marshes. The lakeward boundary of

the marsh would be basically the same with or without the regulation plans in effect (based on Jaworski et al. 1979, definition of wetland boundary as being "the lakeward extent of aquatic vegetation at low levels"). Therefore, it can be assumed there would be a general shrinking of the wetland area and an increased percentage of sedge/meadow and emergent vegetation. Beeton and Rosenburg 1968) state that "...reestablishment of wetlands lakeward during the periods of low water usually does not occur due to exposure to waves and currents".

Since high water levels would occur less frequently, wetland areas would be flooded less frequently than under BOC conditions. Nutrients would, therefore, be released to the wetland less often, adversely affecting the use of the wetland by waterfowl and other wetland-dependent wildlife.

Invasion of the wetland's landward edge by the sedge/meadow zone would become more prevalent. The reduced frequency, extent and duration of high water under a regulation plan might not be sufficient to periodically eliminate the sedge/meadow zones. This would result in a more permanent zone of wetland vegetation that is of lower value to wetland-dependent wildlife species.

It is suggested that, in general, a water level of at least one foot above the mean for a duration of three to five years is required to reduce and/or eliminate dense emergent growth; and that a period of three to five years with water levels at least one foot below mean is required to establish dense emergent-sedge/meadow growth (Dr. I. Bayly and Dr. E. Jaworski, pers. cmm.).

Increased frequency of low water would encourage the development of denser stands of emergents and an expansion of the sedge/meadow zone. An extended duration of high water levels (i.e., 1 foot above long-term mean) would be required to eliminate those dense stands and create conditions for reestablishment of a hemi-marsh. Under regulation, the high water levels of sufficient duration necessary to create these conditions may not occur.

Lake Ontario:

The regulation plans would generally increase the water levels in Lake Ontario, however, the range of fluctuation would be reduced under Category 2 or 3. Therefore, the small variations in lake levels could result in more homogeneous plant communities in most marshes. These communities would be composed of dense cattail or sedges surrounded by shrubs.

Responses of Lake Ontario wetlands to long-term changes of water levels as a result of regulation can be summarized as follows.

A slight increase in the long-term mean would cause more pronounced hydrophytic vegetative characteristics, and result in a general improvement of habitat conditions for wetland-dependent wildlife.

A moderate increase in the range of fluctuation, as would be under Category 1, may enlarge the wetland area (depending on backslope), and would encourage plant species diversity.

A slight increase in the high water levels may increase the wetland area and benefit wetland-dependent wildlife, however, a large increase could eliminate large stands of emergents, create extensive open areas, and adversely affect wildlife. Similarly, a permanent rise with no subsequent low years would also be detrimental.

A general increase in the low water levels would reduce the predominance of the sedge/meadow zone at low water periods.

An increased frequency and duration of high water levels would, in general, promote greater interspersion of vegetation and open water and reduce the extent of the sedge/meadow zone. However, at extreme high levels, an increased incidence of emergent die-back would occur, which would be detrimental to wetland-dependent wildlife.

A reduction in the predominance of the sedge/meadow zone at low water would result from a reduced frequency and duration of low water levels.

4.5.2 Effects of Regulation Plans on the Seven Wetland Types

This section presents the general response of the seven wetland types to water level changes of the order of magnitude expected with the regulation plans. Section 4.4 discusses the vegetative changes in wetland types which occur through the natural fluctuations in water levels. The type and degree of response of each wetland type depends largely on the soil, bottom contour, and backslope characteristics of the individual wetland. For the purpose of this study, the assumption has been made that all wetlands within the same wetland type will exhibit similar responses to given water level alterations. However, it must be remembered that each wetland is unique. No two would react in exactly the same manner.

Table F-30 summarizes the changes which may occur in each wetland type due to limited regulation of Lake Erie.

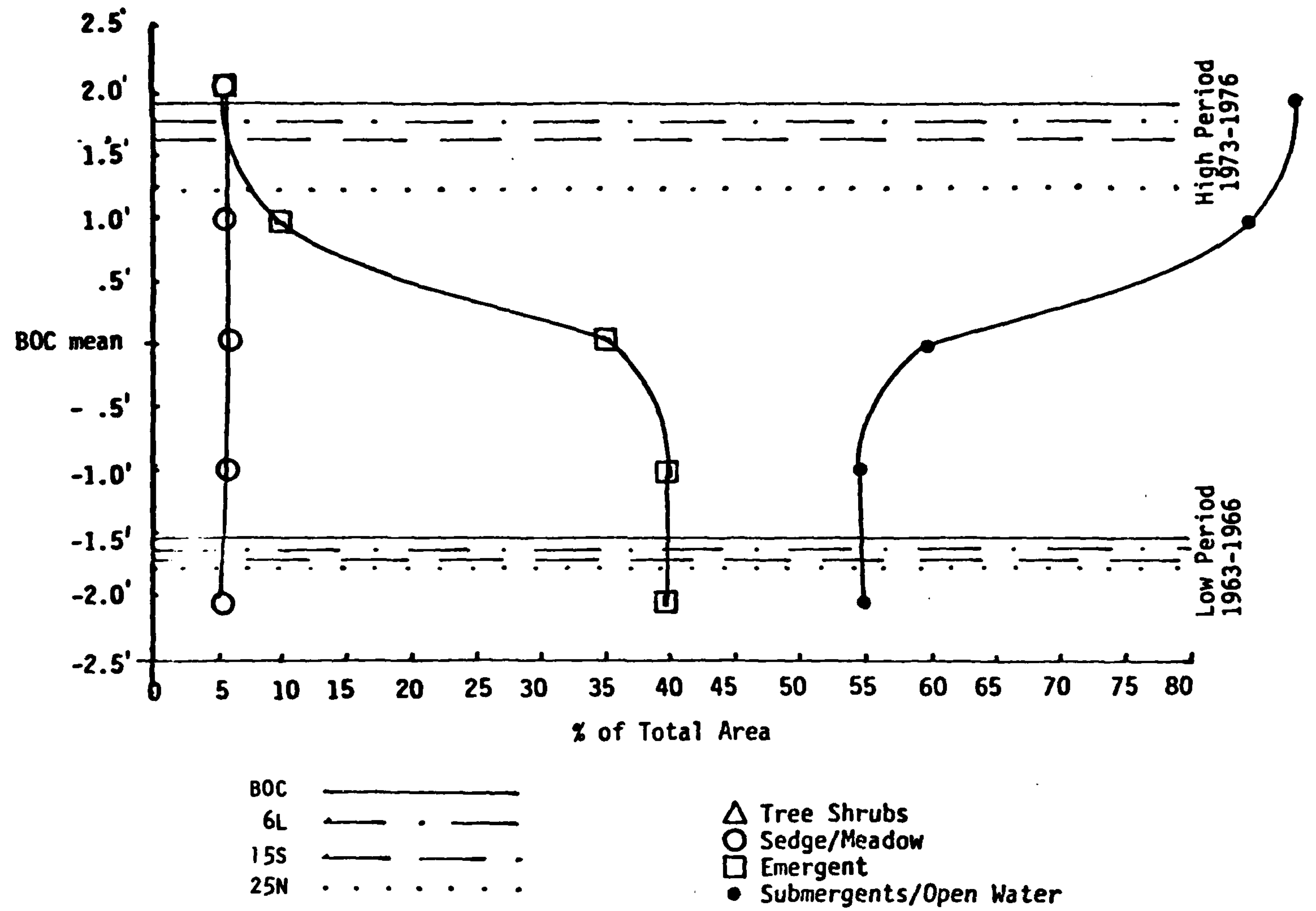
4.5.3 Predicted Vegetative Changes in Specific Wetlands Due to Regulation

Based on a study by Jaworski et al. (1979), and also work by Bayly (1979) and Snell and Donaldson (1979), graphs were developed to illustrate changes in vegative zones resulting from water level changes for eight wetlands. Figs. F-29 to F-35 show the changes in vegetation zones of selected wetlands in Lakes St. Clair, Erie and Ontario. The symbols on the curved line in Figs. F-29, F-31, F-32, F-34 and F-35 represent estimated values furnished by Bayly and Snell. Each symbol on Figs. F-30 and F-33 represent field measurements taken from Jaworski et al. (1979).

Table F-30

General Response of Wetland Types to Regulation

Wetland Types	Lowered Water Levels Lakes St. Clair and Erie	*Increased Water Levels* Lake Ontario
Open Shoreline	A lowering of water levels would result in a lakeward shift of vegetation zones, leaving a dry zone (shrub/tree) at the landward edge. Emergents and sedge/meadow zones would become more prevalent.	The magnitude of change of Lake Ontario water levels, as a result of proposed regulation plans does not permit a distinction to be made between Wetland Types. In general, a slight improvement of wetland conditions may occur with the predominance of sedge/meadow zones *reduced at low water periods. However*, at time of high water, an increase may prove detrimental in some wetlands, with the die-back of emergent vegetation increasing to too great a degree. Lake-connected inland wetlands may experience detrimental die-backs of emergent vegetation during high water levels.
Unrestricted Bay	Lowered water levels would encourage the growth of dense emergents at the expense of open-water aquatics.	
Shallow-Sloping Beach	A lowering of water levels may result in vegetation zone shifts over large areas, with extensive sections of the wetlands exhibiting more mesophytic vegetative characteristics. *Critical wildlife areas could experience* significant damage.	
River Delta	Lower water levels would cause a lakeward shift of vegetation zones, but sedge/meadow zones would be more prevalent at the expense of open-water aquatics.	
Restricted Riverine	These wetlands would become dominated by emergent and sedge/meadow zones in response to lowered water levels.	
Lake-Connected Inland	Lowering of the long-term water levels would result in the loss of wetland along the landward perimeter. *Sedge/meadow and emergent zones would become* prevalent for longer periods and the diversity of wildlife would be reduced. *Effects of lowered lake levels may be most severe in this Wetland Type.*	
Protected	Natural. These wetlands would exhibit denser emergent vegetation and an increase in the extent of the sedge/meadow zones. Dyked. These wetlands could shift to denser emergent vegetation with extreme lowering. Management techniques would offset slightly lowered water levels.	



NOTE: Symbols for each vegetation zone are predicted (not actual) from Bayly (1979).

Figure F-29: Expected vegetation structure at various lake levels for Big Point Marsh (Type 1) Lake St. Clair.

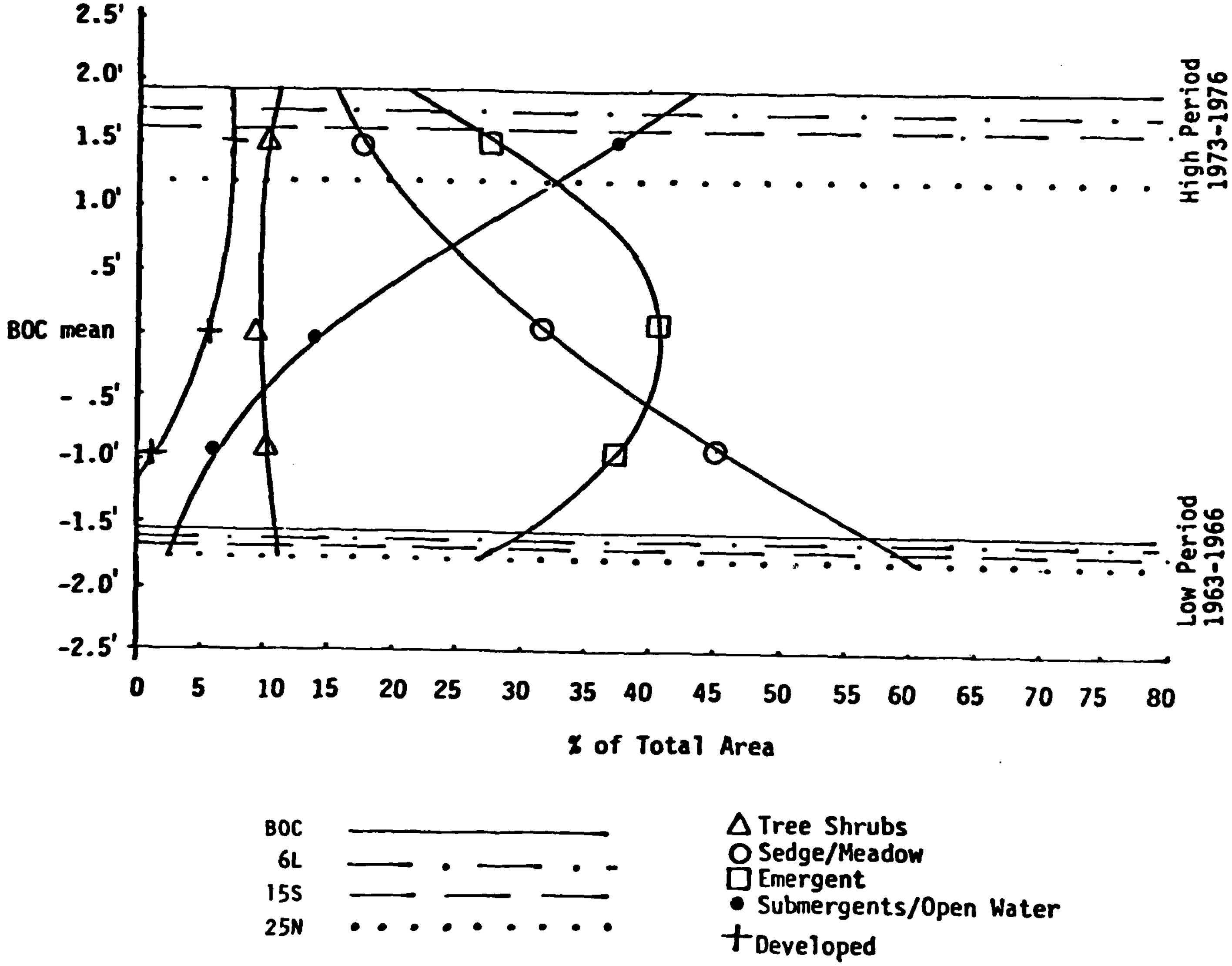
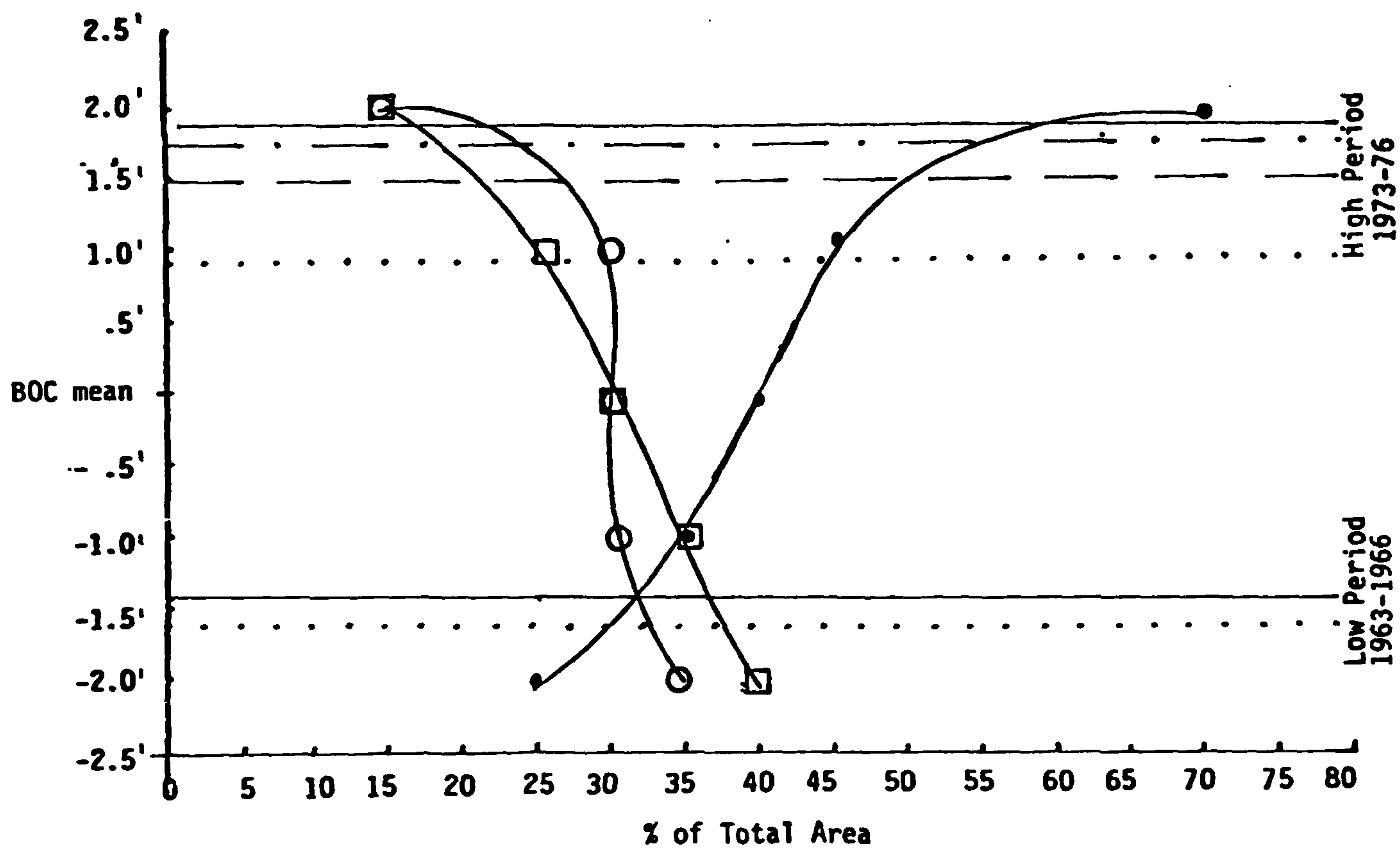
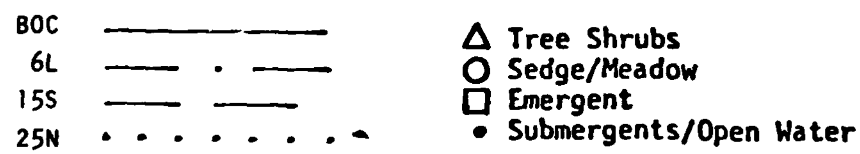


Figure F-30: Expected vegetation structure at various lake levels for Dickinson Island Marsh (Type 4) Lake St. Clair.



Low water period for the BOC, 6L and 15S plans are within .05 feet.



NOTE: Symbols for each vegetation zone are predicted (not actual) from Bayly (1979).

Figure F-31: Expected vegetation structure at various water levels for Long Point Company Marsh, Lake Erie (Type 3).

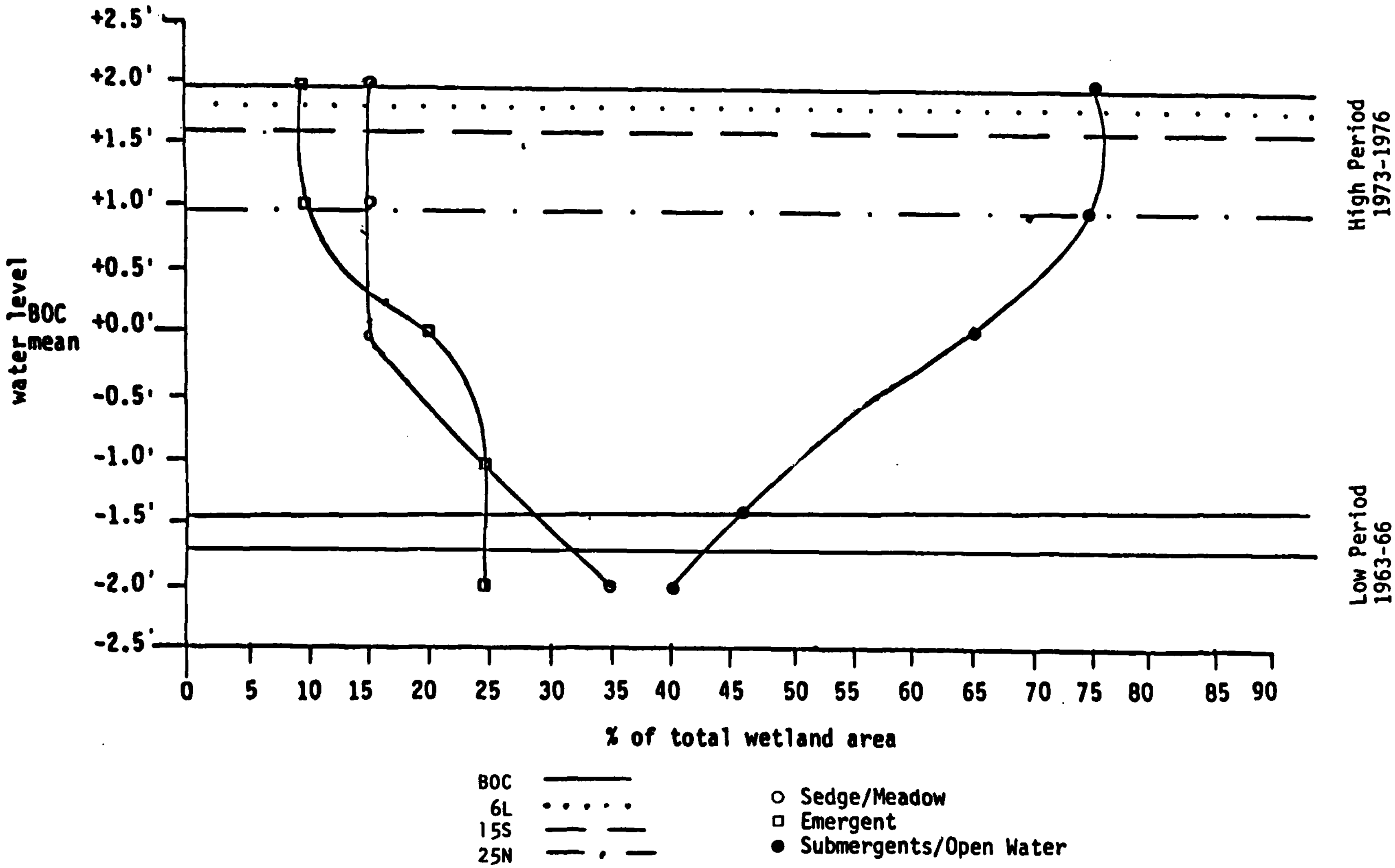
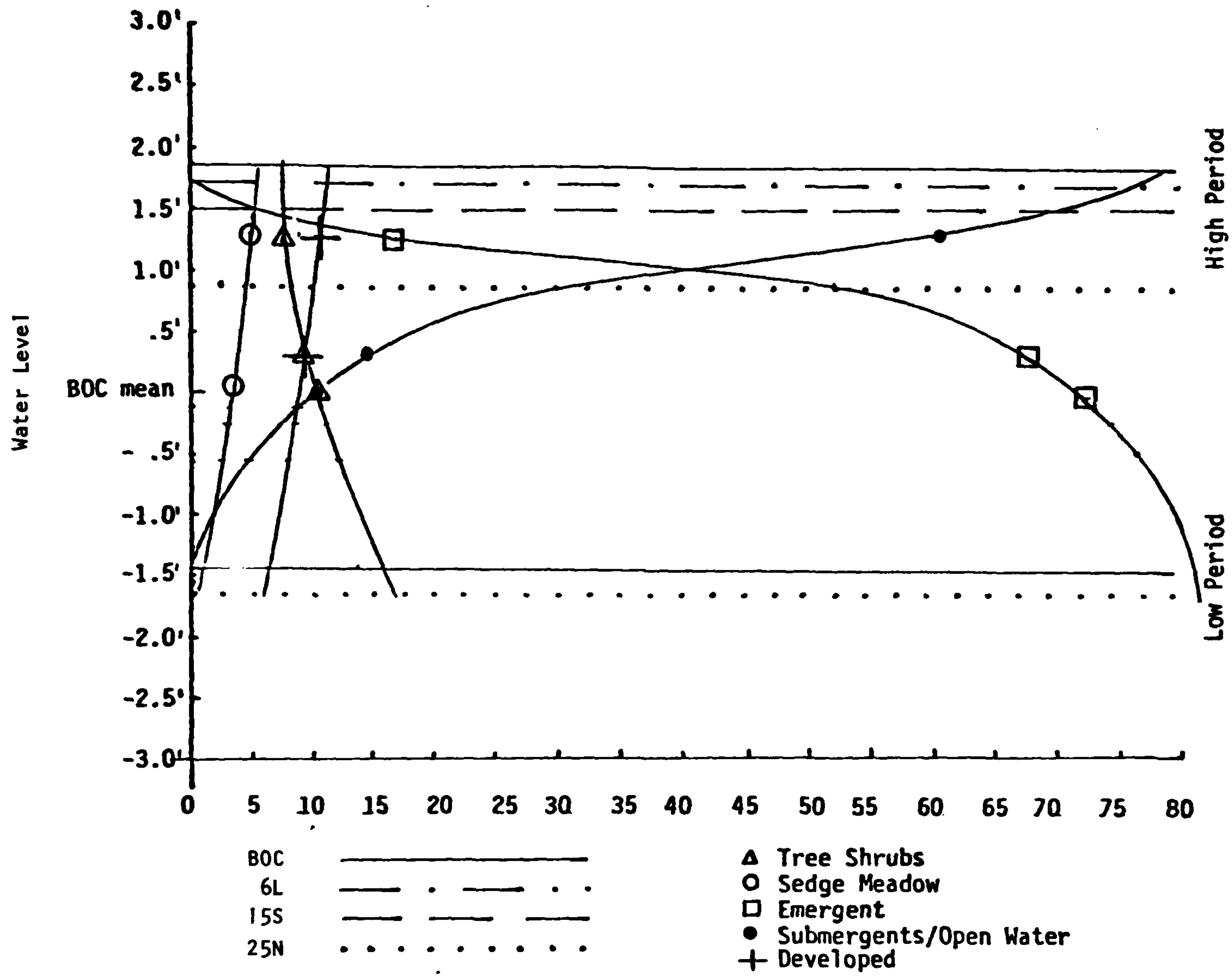
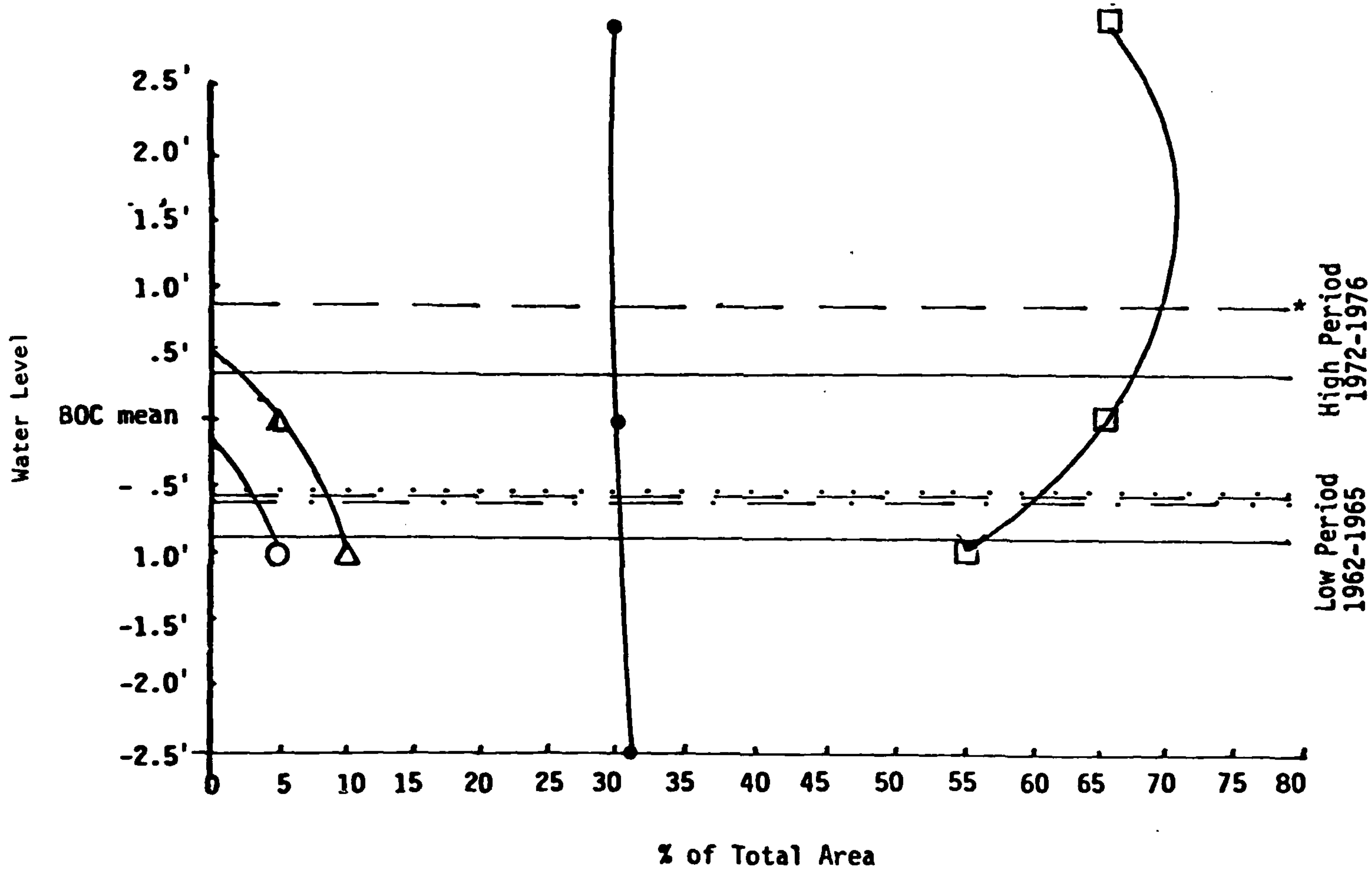


Figure F-32: Big Creek/Holiday Beach (Type 6) Lake Erie.



NOTE: Low Period is 1963-1966, high period is 1973-1976.

Figure F-33: *Expected vegetation structure at various lake levels for Toussaint Marsh (Type 7) Lake Erie.*



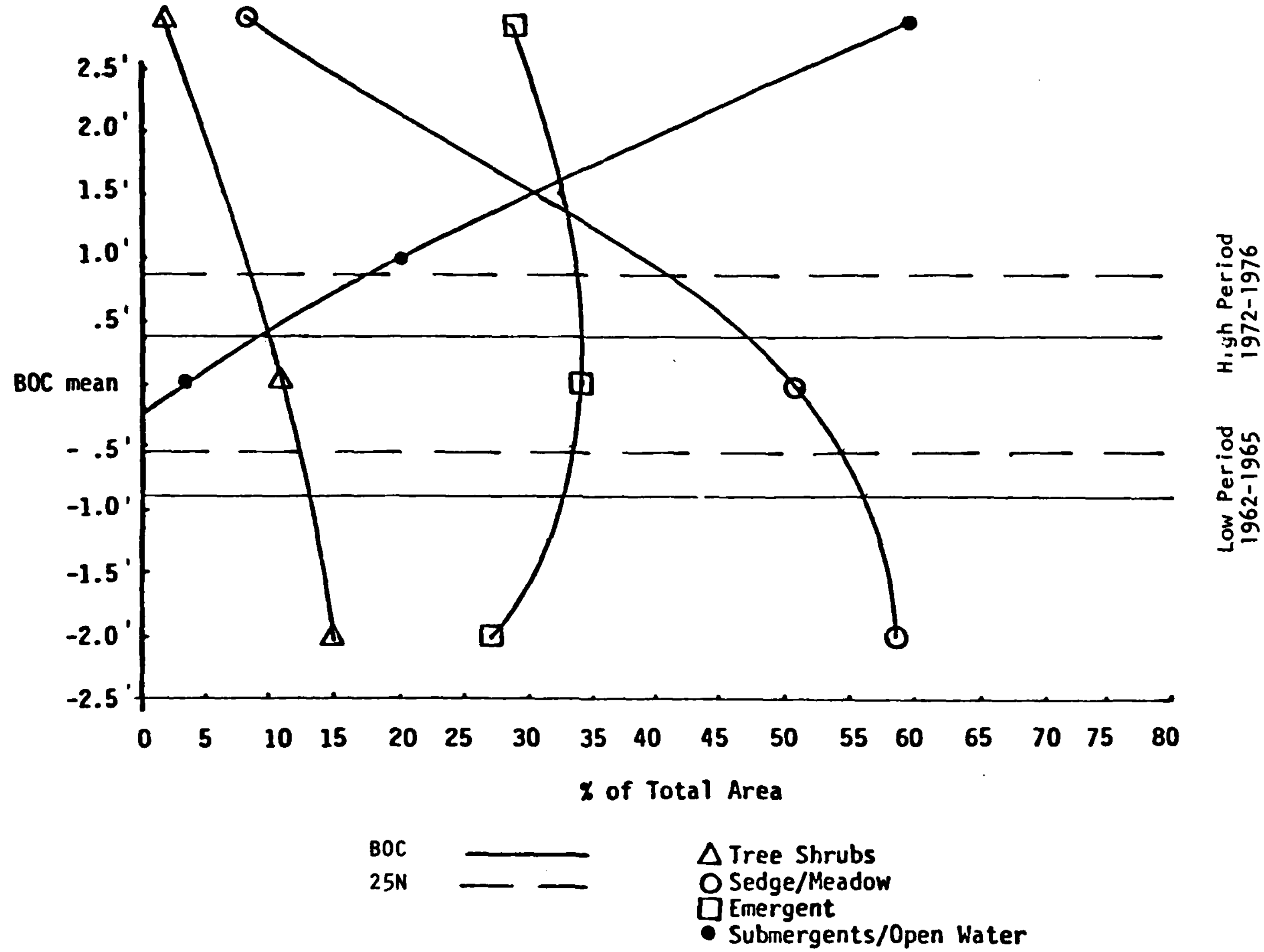
BOC ————
6L —— · ——
15S —— ——
25N · · · · · ·

△ Tree Shrubs
○ Sedge/Meadow
□ Emergent
● Submergents/Open Water

NOTE: Symbols for each vegetation zone are predicted (not actual) from Snell (1979).

* At highwater period all plans are within .05 feet.

Figure F-34: Expected vegetation structure of various water levels for Big Island Marsh (Type 2) Lake Ontario.



NOTE: Symbols for each vegetation zone are predicted (not actual).

Figure F-35: Expected vegetation structure at various water levels for Gravelly Bay Marsh (Type 6) Lake Ontario.

The symbols for each vegetative zone were connected using a smooth curve. The resultant line, based on professional judgement, represents the most likely condition at various water levels. The X-axis (horizontal) represents the percent of the total wetland area and the Y-axis (vertical) represents the variation of the water levels about the BOC long-term annual mean. Thus, for any water level, a percent of the total wetland area covered by any vegetative zone can be predicted.

The high and low water levels for the BOC and for each regulation plan as depicted on these figures are an average of four consecutive years of highest or lowest water levels in the last 20 years. A four-year time period was selected since it takes three to five years of sustained water levels for the vegetative structure to develop.

Acreages of each vegetative zone could be calculated for water levels of the BOC and the plans based on the percentage of the total wetland area which the zone comprises at the various levels. From this, the acreage difference in each of the vegetative zones under the BOC and the plans could be determined. For the purposes of these calculations, it was assumed that the total wetland area would not change due to regulation.

Tables F-31, F-33, F-35, F-37, F-39, F-41 and F-43 show the area of each vegetative zone and the percent of the total wetland area each zone would represent under the BOC. Areal changes of each of these vegetative zones due to regulation are shown on Tables F-32, F-34, F-36, F-38, F-40, F-42 and F-44. A positive number indicates a greater percent or greater area of that vegetative type with the regulation plan in effect.

It can be seen that on Lake St. Clair and Lake Erie, in comparison to BOC, all regulation plans would decrease open water aquatics and increase sedge/meadow and emergent zones for high, mean, and low water periods.

Fig. F-33 shows vegetation changes which could be expected in Toussaint Marsh, Lake Erie. This is a diked marsh and hence is not as dependent on lake-level changes (except at the extreme high levels) as a more open marsh would be. This marsh was flooded during the early 1970's as a result of the dikes breaking. A curve was drawn to point out the abrupt changes which occurred after the dike failure. The exact level at which the dike would breach is not known. An estimate was made based on the highest levels previously recorded prior to the period when the dyke failed. Little change was recorded in the sedge/meadow and tree/shrub zones, conversely, large changes occurred in the emergent and open water/floating/submergent zones. It should be noted that investigation of the marsh in 1978 revealed "...considerable recovery of the cattail and other emergent communities..." Jaworski et al. 1979). The vegetation changes seen at the average water levels are probably a result of the diking and management of the marsh.

Table F-31

Area of Vegetative Zones for Big Point
Marsh, Lake St. Clair
(Type 1)

Basis of Comparison						
Vegetation Type	High Period		Mean		Low Period	
	Acres	Percent of Total Area	Acres	Percent of Total Area	Acres	Percent of Total Area
Trees/Shrubs	-	-	-	-	-	-
Sedge/Meadow	125	5	125	5	125	5
Emergents	125	5	875	35	1,000	40
Open Water/Submergent/ Floating	2,250	90	1,500	60	1,375	55
Total	2,500	100	2,500	100	2,500	100

Table F-32

Areal Changes in Vegetative Zones
for
Big Point Marsh, Lake St. Clair
(Type 1)

(a) High Period (1973-1976)

Vegetative Type	Plan 25N		Plan 15S		Plan 6L	
	Acreage[1] Difference	Percent[2] Change	Acreage Difference	Percent Change	Acreage Difference	Percent Change
Trees/Shrubs	-	-	-	-	-	-
Sedge/Meadow	0	0	0	0	0	0
Emergents	+50	+40	0	0	0	0
Open Water/Submergent/ Floating	-50	- 2	0	0	0	0

(b) Long-Term Annual Mean

Vegetative Type	Plan 25N		Plan 15S		Plan 6L	
	Acreage[1] Difference	Percent[2] Change	Acreage Difference	Percent Change	Acreage Difference	Percent Change
Trees/Shrubs	-	-	-	-	-	-
Sedge/Meadow	0	0	0	0	0	0
Emergents	+75	+9	+25	+3	+25	+3
Open Water/Submergent/ Floating	-75	-5	-25	-2	-25	-2

(c) Low Period (1963-1966)

Vegetative Type	Plan 25N		Plan 15S		Plan 6L	
	Acreage[1] Difference	Percent[2] Change	Acreage Difference	Percent Change	Acreage Difference	Percent Change
Trees/Shrubs	-	-	-	-	-	-
Sedge/Meadow	0	0	0	0	0	0
Emergents	0	0	0	0	0	0
Open Water/Submergent/ Floating	0	0	0	0	0	0

[1]Acreage Difference = (A' - A) X total wetland acreage.

[2]Percent Change in Vegetative Zone = $\frac{A' - A}{A}$

A' = Percent of total wetland area under Regulation Plan
A = Percent of total wetland area under BOC.

Note: In each of the above footnotes, A' and A are derived from graphs such as Fig F-29

Table F-33

Area of Vegetative Zones
for
Dickinson Island, Lake St. Clair
(Type 4)

Vegetation Type	Basis of Comparison					
	High Period		Mean		Low Period	
	Acres	Percent of Total Area	Acres	Percent of Total Area	Acres	Percent of Total Area
Trees/Shrubs	308	11	252	9	308	11
Sedge/Meadow	448	16	896	32	1,568	56
Emergents	588	21	1,120	40	840	30
Open Water/Submergent/ Floating	1,232	44	392	14	84	3
Developed*	224	8	140	5	0	0
Total	2,800	100	2,800	100	2,800	100

*The developed lands from this table have increased through the years not necessarily as a result of water levels. These areas would probably not decrease in numbers or size but would instead increase since once the development has taken place, having them revert to productive wetlands is highly unlikely.

If we were to use the values from Figure F-31 as representative all of Lake St. Clair River Delta Type Wetlands, we would have area differences such as these:

Acreage Differences at High Period

	Plan 25 N	Plan 15S	Plan 6L
Sedge Meadow	+735	+245	0
Emergents	+2,693	+1,224	+735
Open Water/Submerged/ Floating	-2,938	-1,224	-735

Table F-34

Areal Changes in Vegetative Zones
for
Dickinson Island, Lake St. Clair
(Type 4)

(a) High Period (1973-1976)

Vegetative Type	Plan 25N		Plan 15S		Plan 6L	
	Acreage[1] Difference	Percent[2] Change	Acreage Difference	Percent Change	Acreage Difference	Percent Change
Trees/Shrubs	- 28	- 9	- 0	- 0	0	0
Sedge/Meadow	+ 84	+19	+ 28	+ 6	0	0
Emergents	+336	+52	+140	+24	+84	+14
Open Water/Submergent/ Floating	-308	-27	-140	-11	-84	- 7

(b) Long-Term Annual Mean

Vegetative Type	Plan 25N		Plan 15S		Plan 6L	
	Acreage[1] Difference	Percent[2] Change	Acreage Difference	Percent Change	Acreage Difference	Percent Change
Trees/Shrubs	0	0	0	0	0	0
Sedge/Meadow	+140	+16	+28	+3	+28	+3
Emergents	0	0	0	0	0	0
Open Water/Submergent/ Floating	-112	-29	-28	-7	-28	-7

(c) Low Period (1963-1966)

Vegetative Type	Plan 25N		Plan 15S		Plan 6L	
	Acreage[1] Difference	Percent[2] Change	Acreage Difference	Percent Change	Acreage Difference	Percent Change
Trees/Shrubs	0	0	0	0	0	0
Sedge/Meadow	+112	+ 7	+84	+ 5	+28	+2
Emergents	- 84	-10	-56	- 7	-28	-3
Open Water/Submergent/ Floating	- 28	-33	-28	0	0	0

[1]Acreage Difference = (A' - A) X total wetland acreage.

[2]Percent Change in Vegetative Zone = $\frac{A' - A}{A}$

A' = Percent of total wetland area under Regulation Plan
A = Percent of total wetland area under BOC.

Note: In each of the above footnotes, A' and A are derived from graphs such as preceding Fig. F-30

Table F-35

Area of Vegetative Zones for Long Point
Co. Marsh, Lake Erie
(Type 3)

Vegetation Type	Basis of Comparison					
	High Period		Mean		Low Period	
	Acres	Percent of Total Area	Acres	Percent of Total Area	Acres	Percent of Total Area
Trees/Shrubs	-	-	-	-	-	-
Sedge/Meadow	1,725	23	2,250	30	2,400	32
Emergents	1,350	18	2,250	30	2,400	36
Open Water/Submergent/ Floating	4,425	59	3,000	40	2,700	32
Total	7,500	100	7,500	100	7,500	100

Table F-36

Areal Changes in Vegetative Zones
for
Long Point Co. Marsh, Lake Erie
(Type 3)

(a) High Period (1973-1976)

Vegetative Type	Plan 25N		Plan 15S		Plan 6L	
	Acreage[1] Difference	Percent[2] Change	Acreage Difference	Percent Change	Acreage Difference	Percent Change
Trees/Shrubs	-	-	-	-	-	-
Sedge/Meadow	+ 525	+30	+375	+22	+150	+ 9
Emergents	+ 525	+39	+300	+22	+150	+11
Open Water/Submergent/ Floating	-1050	-24	-675	-15	-300	- 7

(b) *Long-Term Annual Mean*

Vegetative Type	Plan 25N		Plan 15S		Plan 6L	
	Acreage[1] Difference	Percent[2] Change	Acreage Difference	Percent Change	Acreage Difference	Percent Change
Trees/Shrubs	-	-	-	-	-	-
Sedge/Meadow	0	0	0	0	0	0
Emergents	+225	10	+150	7	+75	+3
Open Water/Submergent/ Floating	-225	- 8	-150	-5	-75	-3

(c) Low Period (1963-1966)

Vegetative Type	Plan 25N		Plan 15S		Plan 6L	
	Acreage[1] Difference	Percent[2] Change	Acreage Difference	Percent Change	Acreage Difference	Percent Change
Trees/Shrubs	-	-	-	-	-	-
Sedge/Meadow	+ 75	+3	+ 75	+3	+ 75	+3
Emergents	+754	+3	+ 75	+3	+ 75	+3
Open Water/Submergent/ Floating	-150	-6	-150	-6	-150	-6

[1]Acreage Difference = (A' - A) X total wetland acreage.

[2]Percent Change in Vegetative Zone = $\frac{A' - A}{A}$

A' = Percent of total wetland area under Regulation Plan
A = Percent of total wetland area under BOC.

Note: In each of the above footnotes, A' and A are derived from graphs such as preceding Fig. F-31

Table F-37

Area of Vegetative Zones for Big Creek/
Holiday Beach, Lake Erie
(Type 6)

Vegetation Type	Basis of Comparison					
	High Period		Mean		Low Period	
	Acres	Percent of Total Area	Acres	Percent of Total Area	Acres	Percent of Total Area
Trees/Shrubs	-	-	-	-	-	-
Sedge/Meadow	176	15	176	15	340	29
Emergents	117	10	235	20	293	25
Open Water/Submergent/ Floating	880	75	762	65	540	46
Total	1,173	100	1,173	100	1,173	100

Table F-38

Areal Changes in Vegetative Zones
for
Big Creek/Holiday Beach, Lake Erie
(Type 6)

(a) High Period (1973-1976)

Vegetative Type	Plan 25N		Plan 15S		Plan 6L	
	Acreage[1] Difference	Percent[2] Change	Acreage Difference	Percent Change	Acreage Difference	Percent Change
Trees/Shrubs	-	-	-	-	-	-
Sedge/Meadow	0	0	0	0	0	0
Emergents	0	0	0	0	0	0
Open Water/Submergent/ Floating	0	0	0	0	0	0

(b) Long-Term Annual Mean

Vegetative Type	Plan 25N		Plan 15S		Plan 6L	
	Acreage[1] Difference	Percent[2] Change	Acreage Difference	Percent Change	Acreage Difference	Percent Change
Trees/Shrubs	-	-	-	-	-	-
Sedge/Meadow	+ 59	+33	+12	+7	+12	+7
Emergents	+ 47	+20	+12	+5	+12	+5
Open Water/Submergent/ Floating	-106	-14	-24	-3	-24	-2

(c) Low Period (1963-1966)

Vegetative Type	Plan 25N		Plan 15S		Plan 6L	
	Acreage[1] Difference	Percent[2] Change	Acreage Difference	Percent Change	Acreage Difference	Percent Change
Trees/Shrubs	-	-	-	-	-	-
Sedge/Meadow	+35	+10	+35	+10	+35	+10
Emergents	0	0	0	0	0	0
Open Water/Submergent/ Floating	-35	-6	-35	-6	-35	-6

[1]Acreage Difference = (A' - A) X total wetland acreage.

[2]Percent Change in Vegetative Zone = $\frac{A' - A}{A}$

A' = Percent of total wetland area under Regulation Plan
A = Percent of total wetland area under BOC.

Note: In each of the above footnotes, A' and A are derived from graphs such as preceding Fig. F-32

Table F-39

Area of Vegetative Zones for Toussaint Marsh, Lake Erie
(Type 7)

	Basis of Comparison					
	High Period		Mean		Low Period	
Vegetation Type	Acres	Percent of Total Area	Acres	Percent of Total Area	Acres	Percent of Total Area
Trees/Shrubs	124	7	177	10	265	15
Sedge/Meadow	88	5	35	2	18	1
Emergents	0	0	1,236	70	1,395	79
Open Water/ Submergent/ Floating	1,377	78	177	10	0	0
Developed*	177	10	141	8	88	5
TOTAL	1,766	100	1,766	100	1,766	100

* The developed lands from this table have increased through the years not necessarily as a result of water levels. These areas would probably not decrease in numbers or size but would instead increase as the development takes place. A return to productive wetlands is highly unlikely.

Table F-40

Areal Changes in Vegetative Zones
for
Toussaint Marsh, Lake Erie
(Type 7)

(a) High Period (1973-1976)

Vegetative Type	Plan 25N		Plan 15S		Plan 6L	
	Acreage[1] Difference	Percent[2] Change	Acreage Difference	Percent Change	Acreage Difference	Percent Change
Trees/Shrubs	+ 18	+14	0	0	0	0
Sedge/Meadow	- 18	-20	0	0	0	0
Emergents	+918	NI	+ 88	NI	+18	NI
Open Water/Submergent/ Floating	-848	-62	-141	-10	-53	-4

*NI - Not identifiable.

(b) Long-Term Annual Mean

Vegetative Type	Plan 25N		Plan 15S		Plan 6L	
	Acreage[1] Difference	Percent[2] Change	Acreage Difference	Percent Change	Acreage Difference	Percent Change
Trees/Shrubs	+18	+10	0	0	0	0
Sedge/Meadow	0	0	0	0	0	0
Emergents	88	+ 7	+71	+ 6	53	+ 4
Open Water/Submergent/ Floating	88	-50	-35	-20	-18	-10

(c) Low Period (1963-1966)

Vegetative Type	Plan 25N		Plan 15S		Plan 6L	
	Acreage[1] Difference	Percent[2] Change	Acreage Difference	Percent Change	Acreage Difference	Percent Change
Trees/Shrubs	0	0	0	0	0	0
Sedge/Meadow	0	0	0	0	0	0
Emergents	0	0	0	0	0	0
Open Water/Submergent/ Floating	0	0	0	0	0	0

[1]Acreage Difference = (A' - A) X total wetland acreage.

[2]Percent Change in Vegetative Zone = $\frac{A' - A}{A}$

A' = Percent of total wetland area under Regulation Plan
A = Percent of total wetland area under BOC.

Note: In each of the above footnotes, A' and A are derived from graphs such as preceding the Figure F-33.

Table F-41

Area of Vegetative Zones for Big Island Marsh,
Lake Ontario
(Type 2)

Vegetation Type	Basis of Comparison					
	High Period		Mean		Low Period	
	Acres	Percent of Total Area	Acres	Percent of Total Area	Acres	Percent of Total Area
Trees/Shrubs	54	3	90	5	181	10
Sedge/Meadow	0	0	0	0	90	5
Emergents	1,212	67	1,176	65	995	55
Open Water/Submergent/ Floating	543	30	543	30	543	30
Total	1,809	100	1,809	100	1,809	100

Table F-42

Areal Changes in Vegetative Zones
for
Big Island Marsh, Lake Ontario
(Type 2)

(a) High Period (1972-1976)

Vegetative Type	Plan 25N		Plan 15S		Plan 6L	
	Acreage[1] Difference	Percent[2] Change	Acreage Difference	Percent Change	Acreage Difference	Percent Change
Trees/Shrubs	-54	NI	-54	NI	-54	NI
Sedge/Meadow	0	0	0	0	0	0
Emergents	+54	+6	+54	+6	+54	+6
Open Water/Submergent/ Floating	0	0	0	0	0	0

*NI - Not Identifiable.

(b) Long-Term Annual Mean

Vegetative Type	Plan 25N		Plan 15S		Plan 6L	
	Acreage[1] Difference	Percent[2] Change	Acreage Difference	Percent Change	Acreage Difference	Percent Change
Trees/Shrubs	-18	-20	-18	-20	-18	-20
Sedge/Meadow	0	0	0	0	0	0
Emergents	+18	+ 2	+18	+ 2	+18	+ 2
Open Water/Submergent/ Floating	0	0	0	0	0	0

(c) Low Period (1963-1966)

Vegetative Type	Plan 25N		Plan 15S		Plan 6L	
	Acreage[1] Difference	Percent[2] Change	Acreage Difference	Percent Change	Acreage Difference	Percent Change
Trees/Shrubs	-36	-20	-36	-20	-36	-20
Sedge/Meadow	-54	-60	-54	-60	-54	-60
Emergents	+90	+ 9	+90	+ 9	+90	+ 9
Open Water/Submergent/ Floating	0	0	0	0	0	0

[1]Acreage Difference = (A' - A) X total wetland acreage.

[2]Percent Change in Vegetative Zone = $\frac{A' - A}{A}$

A' = Percent of total wetland area under Regulation Plan
A = Percent of total wetland area under BOC.

Note: In each of the above footnotes, A' and A are derived from graphs such as preceding the Figure F-34.

Table F-43

Area of Vegetative Zones for Gravelly Bay, Lake Ontario
(Type 6)

Vegetation Type	Basis of Comparison					
	High Period		Mean		Low Period	
	Acres	Percent of Total Area	Acres	Percent of Total Area	Acres	Percent of Total Area
Trees/Shrubs	33	10	36	11	43	13
Sedge/Meadow	151	46	167	51	180	55
Emergents	111	34	112	34	105	32
Open Water/Submergent/ Floating	33	10	13	4	0	0
Total	328	100	328	100	328	100

Table F-44

Areal Changes in Vegetative Zones
for
Gravelly Bay, Lake Ontario
(Type 6)

(a) High Period (1972-1976)

Vegetative Type	Plan 25N		Plan 15S		Plan 6L	
	Acreage[1] Difference	Percent[2] Change	Acreage Difference	Percent Change	Acreage Difference	Percent Change
Trees/Shrubs	+ 3	+10	- 3	-10	- 3	-10
Sedge/Meadow	-20	-13	-20	-13	-20	-13
Emergents	0	0	0	0	0	0
Open Water/Submergent/ Floating	+23	+70	+23	+70	+23	+70

(b) Long-Term Annual Mean

Vegetative Type	Plan 25N		Plan 15S		Plan 6L	
	Acreage[1] Difference	Percent[2] Change	Acreage Difference	Percent Change	Acreage Difference	Percent Change
Trees/Shrubs	0	0	0	0	0	0
Sedge/Meadow	-3	- 2	-3	- 2	-3	- 2
Emergents	0	0	0	0	0	0
Open Water/Submergent/ Floating	+3	+25	+3	+25	+3	-25

(c) Low Period (1963-1966)

Vegetative Type	Plan 25N		Plan 15S		Plan 6L	
	Acreage[1] Difference	Percent[2] Change	Acreage Difference	Percent Change	Acreage Difference	Percent Change
Trees/Shrubs	0	0	0	0	0	0
Sedge/Meadow	-3	-2	-3	-2	-3	-2
Emergents	+3	+3	+3	+3	+3	+3
Open Water/Submergent/ Floating	0	0	0	0	0	0

[1] Acreage Difference = (A' - A) X total wetland acreage.

[2] Percent Change in Vegetative Zone = $\frac{A' - A}{A}$

A' = Percent of total wetland area under Regulation Plan
A = Percent of total wetland area under BOC.

Note: In each of the above footnotes, A' and A are derived from graphs such as Figure F-35.

On Lake Ontario, all regulation plans would increase the open water aquatic zone and decrease the emergent and sedge/meadow zones during high and mean water periods.

4.5.4 Vegetation Zone Shifts and Effects on Wildlife

Lake St. Clair and Lake Erie:

In general, for Lakes St. Clair and Erie, which contain almost 100,000 acres of wetland, the predicted shift to sedge/meadow plant communities, at the expense of reducing the interspersed open-water aquatics and emergent zones, would decrease the diversity and abundance of wetland-dependent wildlife species. Redwinged blackbirds, swamp sparrows, yellowthroats and some terrestrial species (white-tailed deer, cottontail rabbit) would benefit, while wetland-dependent species such as waterfowl, muskrats, coots and gallinules would suffer.

The value of the wetlands to recreationally and commercially important species, such as migratory waterfowl and muskrats, would decrease. Economically important recreational opportunities in fishing, hunting, trapping and non-consumptive uses, which normally improve during average and high water level periods, would likely decrease.

A slight increase in the number of nesting waterfowl may be noticed as a result of increased sedge/meadow zones, but any increase would be insignificant and more than offset by a reduction in the quality of staging habitat. The primary importance of the Great Lakes shoreline wetlands for waterfowl is as a migration staging habitat (Dennis and Chandler 1974). Good quality staging areas require "hemi-marsh" conditions, which provide adequate food and cover plants. Lower water levels would result in poor marsh quality and, therefore, less use by migrating waterfowl. This would likely reduce the hunting opportunities in the Great Lakes shoreline wetlands as waterfowl use declines.

Lower water levels would expose more shoals and low islands which would result in increases in most gull and tern populations. "During previous lows, the gull populations on the lakes increased at phenomenal rates. This occurrence and similar ones in other parts of the country have resulted in unusually large gull populations in the U.S. This has caused a number of problems such as a "serious bird/aircraft hazard" (Dr. Southern, Northern Ill. University, pers. comm.).

Since an increase of sedge/meadow and emergents will result in an increase of large numbers of redwinged blackbirds, crop depredation by the birds in the Lake St. Clair area would probably increase.

Invertebrate numbers could be greatly reduced as the submergent vegetation zones are eliminated. These animals are an important food source for many of the vertebrates, therefore, the higher animals could be indirectly impacted. Reptiles and amphibians would probably experience little impact as a result of the regulation plans.

In reference to Lakes Erie and St. Clair, "...much of the diking of costal wetlands by private and public shooting clubs was carried out during the low-water periods (e.g., 1930's and 1960's) when dense cattail and widespread sedge communities reduced the quality of waterfowl and muskrat habitat..." (Jaworski et al. 1979). Diked wetlands, with a much higher market value than undiked wetlands, are more likely to be drained for an alternate use, usually agriculture. Along the eastern shoreline of Lake St. Clair (Thames River to Chenal Ecarte), from 1965 to 1978, 25 percent of the existing wetlands were destroyed, primarily by agricultural drainage. Of the 2,179 acres that were lost, 91 percent were diked wetlands (McCullough 1979).

Therefore, it appears that the implementation of regulation plans that would lower the water levels of Lakes Erie and St. Clair would also contribute to the destruction of additional wetland acres. The value of those drained wetlands to wetland-dependent wildlife would disappear.

Lake Ontario:

In general, the changes to the water level regime due to limited regulation of Lake Erie would result in less dense growths of emergents and sedge/meadow during the low and mean water periods of the long-term cycles. However, the increased high levels would increase the die-back of emergents in the short-term. Overall, the impacts on Lake Ontario may be regarded as indeterminable to slightly beneficial for wetlands and wetland-dependent wildlife.

The predicted small changes to Lake Ontario water levels, plus the limited information available for Lake Ontario wetlands, do not allow a more detailed examination of the impacts of regulation on the Lake Ontario environment.

St. Lawrence River:

Any increase in water levels in the downstream sections of the St. Lawrence River (Morrisburg-Moses Dam area) would, in general, increase the short-term die-back of emergent vegetation in the shoreline wetlands. Wildlife species dependent upon emergent vegetation for nesting and feeding would suffer in the short-term.

The water level fuctuations currently experienced in the St. Lawrence River are highly variable. This variability combined with the relatively small increases in water levels predicted for even the Plan 25N and the very limited information base for wetlands along the river does not permit detailed analysis of impacts on wetlands to be made within constraints of this study.

4.6 Evaluation Of Structural Effects

The effects of regulatory structures in the Niagara River are described in the following section. These evalations focus on the effects of construction and operation or maintenance.

Local Effect of Structures:

Of the three regulation plans evaluated, only the Niagara River alternatives involve major structures requiring extensive construction work (i.e., dredging and blasting of the Niagara River bottom, cofferdaming, etc.). Plan 25N requires dredging and excavation of the river bottom and construction of gates to control water flows. This would be in the vicinity of the Peace Bridge and protrude into the Niagara River near the southern end of Squaw Island on Bird Island Pier. Plan 15S involves digging a channel through the northern end of Squaw Island near the Black Rock Lock with a gate constructed in the channel. Plan 6L would modify the existing lock gates to allow passage of water.

The impact of the structures themselves on wildlife would probably be minimal. During construction and when maintenance is required there would be an increase in turbidity and sediment load in the river. This increase in turbidity could be damaging to the vegetation in the few wetland areas near the structures or the submergent vegstation in the river itself.

Areas of the Niagara River with waterfowl concentrations include Strawberry Island, the north and south shores of Grand Island and around Old Fort Niagara. Strawberry Island is about 2 miles downstream from Black Rock Lock and about 3-1/2 miles from the Peace Bridge. The wetlands on the south shore of Grand Island are about a half-mile further downstream.

As many as 25,000 waterfowl occupy on the Niagara River especially during the winter months. The common merganser is the most abundant wintering specises. Being piscivores, they would be affected by altered water levels only to the extent that the forage fish populations were depleted. Likewise, the common golden-eyes and scaups feed largely on mollusks, the abundance of which could conceivably change with a decrease in the river depth. The approximately 3,000 canvasbacks which winter on the Niagara River feed primarily on wild celery (Vallisneria americana); the abundance of canvasbacks could be reflected in the availability of this food resource.

Operational Effects:

During operation of the regulatory structures, the higher flows could increase the erosion rate of Strawberry Island and thus impacting on the wetlands of this area.

4.7 Concluding Remarks

4.7.1 Predicted Impacts:

Lake Erie, Lake St. Clair, St. Clair River, Detroit River:

Plan 25N would be the most damaging plan, resulting in permanent loss of some wetland area especially around the landward edges of existing wetlands. A shift in vegetation zones would be expected with sedge/meadow zones becoming more prevalent while open-water/submergent

zones are reduced in area. Due to the increased stability of water levels (reduced fluctuation range), long-term changes would result, through succession, in less diversity of vegetation and more areas of emergents and sedges. Shifts to sedge/meadow/emergent-dominated wetlands would decrease the divesrsity and density of wetland-dependent wildlife (e.g., waterfowl, muskrats), while providing habitat for terrestrial wildlife species.

Plan 15S would also be damaging to the vegetative structure producing increases in sedge/meadow zones at the expense of open-water/submergent zones, and would cause wildlife species shifts. The area loss around the landward edges could still be extensive; however, not as great as Plan 25N. Under Plan 15S, at least for Lake St. Clair, there would be sufficient variability in lake levels to promote species diversity. In Lake Erie, however, there may not be ample variation.

Plan 6L is the least detrimental to the wetlands. However, vegetative zone shifts of lesser magnitudes from open-water aquatics to emergents and sedge/meadow would still occur.

Lake Ontario (Category 2):

All three regulation plans would produce simlilar changes in the lake Ontario water level regime. The impacts of a reduced predominance of sedge/meadow and emergent zones during low and mean water periods and an increased die-back of emergents during increased high water periods are, overall, regarded as indeterminable to slightly beneficial to wetlands and wetland-dependent wildlife.

Lake Ontario (Category 3):

Under Category 3, Lake Ontario water levels would be changed significantly over Category 2 especially in fluctuation range and occurrence of high levels. Under Category 3 the range of fluctuation would be reduced. This reduction would result in a lower wetland vegetation species diversity, with cattail becoming overabundant in most areas.

St. Lawrence River (Category 3):

The dredging along the St. Lawrence River for Category 3 does not directly involve any wetlands or known critical wildlife habitat. The effects, therefore, through direct removal of habitat would be small. The possibility exists, however, of increased turbidity and sediment load during initial dredging and maintenance operations.

High water levels and flows downstream of the dredged areas which could destroy existing wetlands. The higher flows in the river could destroy valuable waterfowl habitat. This may be important in the submerged vegetation beds which are important to diving ducks. Benthic organisms would be removed or eliminated through dredging and the associated silt buildup downstream.

Removal of any islands would also remove mammalian habitat. If the islands were large, the impact could be severe. Gull and tern nesting colonies would be destroyed if water levels increase or the nesting site removed by dredging. Reptiles and amphibians would be affected by dredging, water level fluctuations, and flow changes.

Habitat destruction through disposal of fill material both initially and with maintenance dredging could be significant depending on disposal sites.

4.7.2 Summary

The lowering of the water levels of Lakes Erie and St. Clair could create large areas of sedge marsh and meadow environments, which would decrease the diversity and density of wetland-dependent wildlife species while enhancing habitat conditions for species not necessarily dependent on wetlands. The landward edges of wetlands exposed and no longer periodically flooded would tend to progress to shrubs and trees if left undisturbed by human activity. A more probable result would be the encroachment of development into the resultant dry zone along the perimeter of the wetlands. This might generate additional pressure for converting wetlands to alternate uses.

Research studies are only now looking at the responses of Great Lakes shoreline wetlands to existing water level fluctuations. Wetlands are complex ecosystems and to predict impacts, it is necessary to understand all the processes and interdependencies of the natural system. Little detailed information exists relating fluctuating water levels of the Great lakes to changes in the vegetative composition of shoreline wetlands (at least the major ones) and to the responses of a myriad of wildlife.

4.8 Information Gaps And Study Recommendations

Detailed bottom-contouring data for shoreline wetlands, a critical requirement for predicting wetland vegetation response to altered lake levels, are not available. Detailed information relating to vegetation zone responses to historical water-level fluctuations for Great Lakes shoreline wetlands is almost non-existent. No detailed studies were available that relate those historical shifts of vegetation zones to changes in the diversity and abundance of wetland wildlife species.

Accurate predictions as to what effect altering water level fluctuations would have on wildlife species is impossible based on the absence of applicable information. Therefore, only general responses of wetlands and estimated shifts of species diversity and abundance could be indicated in this evaluation.

A quantitative/qualitative evaluation of the impacts of altered water levels on wetlands and wildlife would require detailed examinations of the Great Lakes shoreline wetlands and detailed examinations of a number of representative subsamples including their physical, chemical and biological characteristics, related to fluctuating water levels over a lengthy period of time (7 to 10 years minimum).

Section 5

FISH

5.1 Introduction

The changes in lake levels due to limited regulation, of Lake Erie though small compared with natural fluctuations, might have serious effects on the fish populations. These impacts would be primarily in shallow inshore areas of the lakes and the connecting channels in the study area, and at the sites considered for regulatory structures. The shallow water environments are the most biologically productive areas of the Great Lakes system. These areas provide important spawning, nursery, and feeding grounds which are essential to the maintenance of fish stocks. Important shallow water areas occur in Lake St. Clair, Lake Erie's western basin, Long Point Bay, the eastern basin of Lake Ontario, and the St. Lawrence River.

This evaluation was based on available data. The identification of cause-effect relationships between water level changes and their impact on fish was based largely on inference and was therefore, qualitative rather than quantitative. Much of the available information on the Great Lakes fish stocks does not lend itself to the evaluation of the impact of lake level regulation. There is a particular lack of information with regard to water level changes on the fish utilizing the nearshore zone.

The study area for the evaluation of the effects of limited regulation of Lake Erie on the fish resources includes the lower Great Lakes and their interconnecting channels. Separate reviews were conducted for the potential impacts of the water level changes on Lakes St. Clair, Erie, and Ontario; the construction and operation of the regulatory works for the Upper Niagara River; and the remedial works in the St. Lawrence River.

5.2 General Approach

Pertinent information and data were reviewed in the evaluation of the potential impacts. Sources of information include published scientific papers, unpublished documents, government data banks, individual knowledge, and definitive lakewide studies.

The International Great Lakes Levels Board Study (IGLLB) showed that the effects of water level regulation in the open lake would be almost impossible to detect. As a result, the evaluation concentrated on selective areas where the impacts of regulation would likely be more readily detected. During this investigation, emphasis was placed on:

1. reviewing the requirements of fish populations of specific nearshore habitats, primarily wetlands and shallow embayments;
2. identifying possible correlations between the abundance of some fish species and

variations in water levels ; and

3. the localized impacts resulting from the required regulatory and remedial works in the Niagara and the St. Lawrence River.

The evaluation of systemic effects was based on the identification of the impacts of long-term (over 4 years) and seasonal water level changes. The nature and severity of the effects in critical nearshore areas and on species sensitive to such level changes, depends on the sequence of levels and flows as well as the magnitude of the change. Thus, attention was focused on impacts due to changes in the long-term mean water levels and also in the frequency, duration, amplitude, and seasonal occurrence of high and low water levels. The very short-term changes in water levels caused by storms, seiches, etc., were not addressed.

Since wetlands are important to the fish resource as food sources and habitat, the wetland review conducted in the wild life evaluation was incorporated in this evaluation. The impacts on fish from changes in water quality and hypolimnion volume as a result of regulation were also examined in light of the findings of the water quality study.

5.3 Existing Conditions

5.3.1 Value of the Lower Great Lakes Fisheries

The lower Great Lakes and connecting channels support over 130 species of fish (Van Meter and Trautman 1970; Crossman and Van Meter 1979). These areas represent some of the most significant freshwater fish habitats of North America (Annex 9).

The lower Great Lakes provide many benefits to the people of Canada and the United States. The Lake Ontario Fisheries Management Committee recognizes the value to society of a healthy fish resource and lists six benefits of this resource (OMNR 1976a). These benefits are:

1. healthy human environment;
2. an abundant supply of fish for human consumption;
3. employment;
4. income;
5. recreational opportunities; and
6. harmonious use.

These benefits apply equally to both of the lower Great Lakes.

The Sport fishing effort in Lake St. Clair and connecting waters by Michigan anglers was estimated at 1,905,300 angler days for 1977. The economic value would be approximately 19 million dollars ($9.72 per angler day, Jaworski and Raphael 1978). The total dockside value of the commercially harvested fishes from the lower Great Lakes (combined U.S. and Canadian) is nearly 14 million dollars (U.S. Fish and Wildlife

Service 1979 and OMNR 1979). The combined U.S. and Canadian commercial fishing industry annually harvests an average of 50 million pounds of fish from Lake Erie and another 2.5 million pounds from Lake Ontario (Baldwin and Saalfield 1962, updated by U.S. Fish and Wildlife Service 1979). In Ontario, the commercial fisheries on the lower Great Lakes employ over one thousand full-or part-time fishermen who have approximately nine million dollars invested in boats, gear, and shore installations (Adams and Kolenosky 1974).

In recent years there has been an increased demand for recreational fishing opportunities and the sport fishing industry in the lower Great Lakes is now a multimillion dollar business. The recreational fishery was estimated at 60 million dollars in 1978 for Ohio waters of Lake Erie alone (ODNR 1979). The Province of Ontario reported 562,000 angler hours in 1978 for Lake Erie (OMNR 1979). Sport fishing on Lake Ontario and the St. Lawrence River is also very important. In the St. Lawrence River, much of the area's economy is linked to the sport fishing industry. Dollar estimates are not available, but are predicted to be in the millions and increasing annually. Summaries of catch statistics for the commercial and sport fisheries of each area can be found in Annex 7.

Traditionally, near-shore warm and cool water fish, such as bass (both largemouth and smallmouth), northern pike, yellow perch, walleye, and muskellunge have been the most sought after species by anglers. Recent introductions of cold or cool-water species have sparked a new interest in offshore recreational fishing. At least 300,000 hours of angling effort is generated each year by Lake Ontario's salmonid recreational fishery (Kolensky and LeTendre 1979). Ontario Ministry of Natural Resources indicates that Lakes Ontario and Erie offer the greatest potential for increasing fishing opportunities (OMNR 1976b).

Fish are very sensitive to environmental changes and can detect hazardous conditions far sooner than man, and in this way can act as water quality indicators. Fish stocks also have a very important biologic value in the aquatic environment. Fish are the climax predators in the aquatic ecosystem and as such they are essential to the flow of energy through the system. In this regard the fish species, including species with different food habits, is extremely important. A system with a diverse fish population with and a wide range of feeding and space habitats results in good resource utilization.

5.3.2 Lake St. Clair

Description of General Area:

The St. Clair River-Lake St. Clair-Detroit River make up the St. Clair Complex. This complex is an important fish habitat and an important nursery area for fish moving to Lakes Huron and Erie.

Because of its shallowness (averaging 10 ft.) light penetrates to the bottom of Lake St. Clair and no thermal stratification occurs. In winter the lake is mostly ice-covered from January to March, except for

the central portion near the navigation channel. Wind action during open water periods maintains oxygen at saturation levels and increases turbidity, particularly in nearshore areas.

The St. Clair River flows from Lake Huron to Lake St. Clair. The water quality of Lake Huron as indicated by benthic communities is good. A highly diverse assemblage of benthic macro invertebrates such as mayflies, caddisflies, oligochaetes, chironomids, snails, and clams can be found throughout the river, except in the dredged shipping channel.

Many of the fish species that can be found in this river move to or from Lakes Huron, St. Clair and Erie for spawning. These species include walleye, muskellunge, rainbow trout, lake sturgeon, smelt, coho and chinook salmon, smallmouth bass, yellow perch, freshwater drum, and channel catfish.

Some St. Clair River species, such as walleyes, support populations elsewhere in the Great Lakes, especially in Lakes Erie and Huron and their tributaries (Wolfert 1963). Since 1974, the Michigan Department of Natural Resources has conducted a walleye tagging project in Anchor Bay. Most of the returns have come from Anchor Bay, with lesser numbers from the upper St. Clair River and southern Lake Huron, suggesting a local stock. A much smaller number of returns came from the Detroit River and western Lake Erie. Fish spawning and nursery areas in the St. Clair River are believed to be in the marshy shallow bay areas, and on the rocky shoals of Stag and Fawn Islands.

The lower end of the St. Clair River forms the St. Clair River Delta which extends into Lake St. Clair and contains approximately 22,700 acres of wetlands important to many species, including northern pike, smallmouth bass, yellow perch, bluegill, and walleye.

Lake St. Clair is a large, round, shallow basin with a gently sloping bottom and a maximum depth of about 21 feet. The near-shore zones, especially on the northern and eastern sections of the lake have large areas of wetland habitats. Because of its shallowness, submergent aquatic vegetation is common throughout the lake; it provides food cover and spawning areas for many fish species. Lake St. Clair is noted for the muskellunge, but also noteworthy is the relatively uncommon lake sturgeon which spawns in the North Channel of the delta area.

The Detroit River is a very heavily developed 31-mile long river. Water quality is gradually improving and sport fishing for freshwater drum, channel catfish, yellow perch, walleye, rock bass and smallmouth bass takes place. The Michigan Department of Natural Resources has been conducting a stocking program (coho and chinook salmon and rainbow trout) to provide more recreational fishing opportunities.

5.3.3 Lake Erie

Description of General Area:

Lake Erie is the shallowest, warmest, and southern most of the Great Lakes. The Lake is naturally divided into three basins (Fig. F-36)

by two cross-lake moraines. These natural geologic divisions are ecologically important because the level of eutrophication is different in each basin (Hartman 1973).

Some major fish spawning and nursery areas in Ohio's waters of the western and central basins are shown in Fig. F-37 to F-40.

The western basin is the shallowest of the three basins of Lake Erie. It has an average depth of 24 feet and contains only five percent of the lake's volume. The basin's many shoals, islands, and rocky reefs make it a very important warmwater fish spawning and nursery area of the lake.

During 1977 the commercial fishery of the western basin harvested approximately 3.2 million pounds of fish with a dockside value approaching 2 million dollars. The major species in this fishery were yellow perch and white bass.

There are three major tributaries (excluding the Detroit River) flowing into Lake Erie's western basin: the Raisin, Maumee and Sandusky Rivers. The Sandusky River enters Sandusky Bay at the eastern end of the western basin. This is one of the most important areas on Lake Erie with respect to the fish resources. Sandusky Bay produced approximately 39 percent of the commercial catch for the State of Ohio (ODNR 1979). In addition, the bay supports a very active, year long, sport fishery. Cold Creek which also flows into the Bay is an important salmonid stream.

The central basin is deeper and larger in volume than the western basin; however, it does not have the features such as islands and shoals that exist in the western basin. Important resource areas of the central basin are listed on Table F-45.

The Canadian waters of the central basin contain two of Ontario's five Lake Erie commercial fish statistical districts (No. OE-2 and OE-3). These two districts produced approximately 53 percent of the total Lake Erie commercial fish catch for Ontario in 1977 with a dockside value of over 4 million dollars. The mainstays of this harvest in order of importance were: smelt, yellow perch, white bass, northern pike and freshwater drum.

Although the central basin supplies a major portion of Lake Erie's commercial fish catch, and has areas of concentrated recreational fishing, very little quantified or even qualified information exists concerning spawning and/or nursery areas within the basin. Rondeau Bay is probably the most important warmwater spawning and nursery area. Northern pike, largemouth bass, carp, rock bass, pumpkinseed, bluegill, bowfin, and numerous cyprinids are the main users of the bay.

The eastern basin, with a maximum depth of 210 feet, is the deepest of the three basins on Lake Erie. Unlike the western and central basins, there are steep slopes of sand and gravel or rock which encircle the deep areas. There is also a thin band of predominantly coarse sand that occurs in the shallow nearshore areas from Port Maitland to Fort Erie (GLBFS 1976).

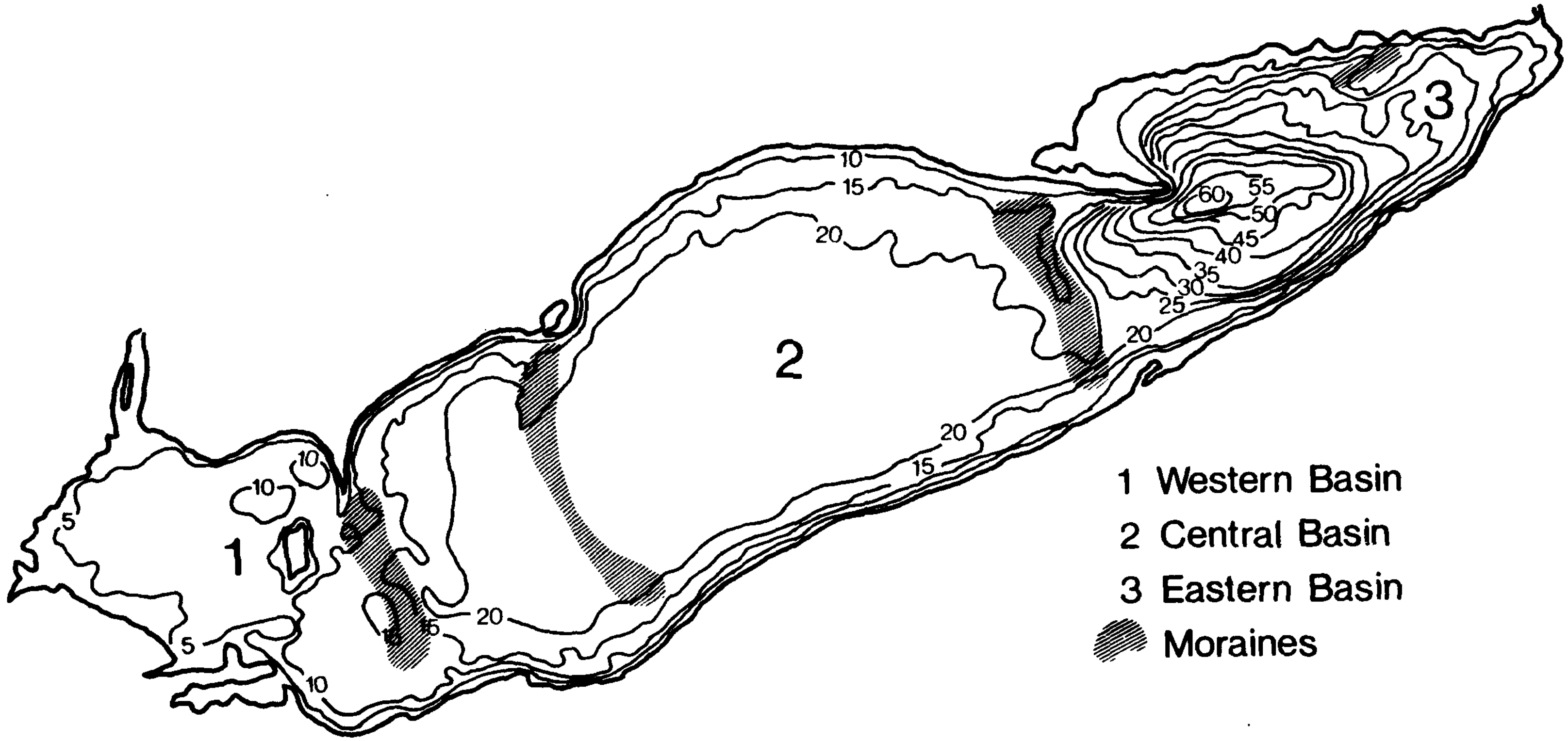


Figure F-36 Bathymetry (metres) of Lake Erie showing cross lake moraines and the three basins.

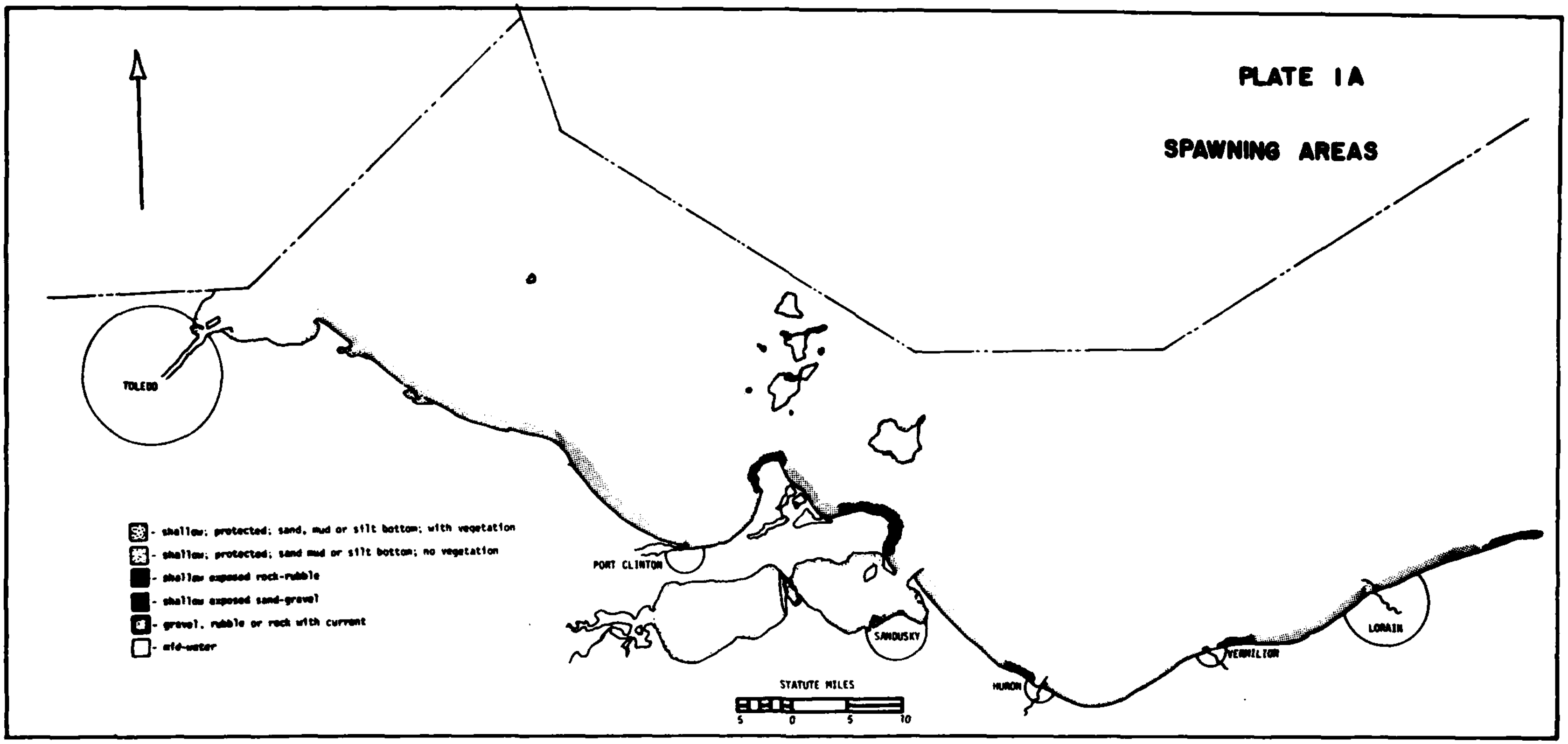


Figure F-37 **Major Spawning Areas in Lake Erie's Western and Central Basins**

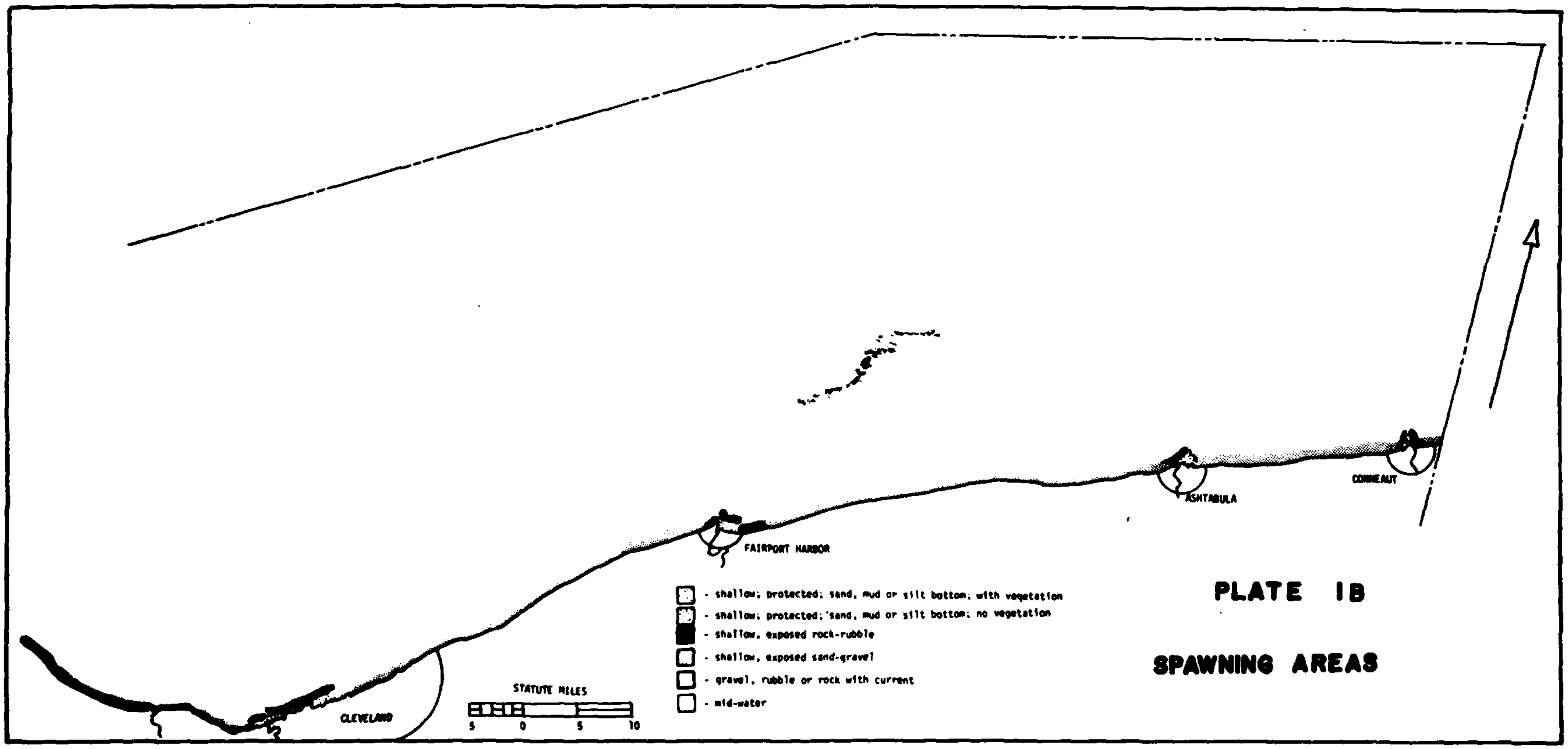


Figure F-38 **Major Spawning Areas in Lake Erie's Central Basin**

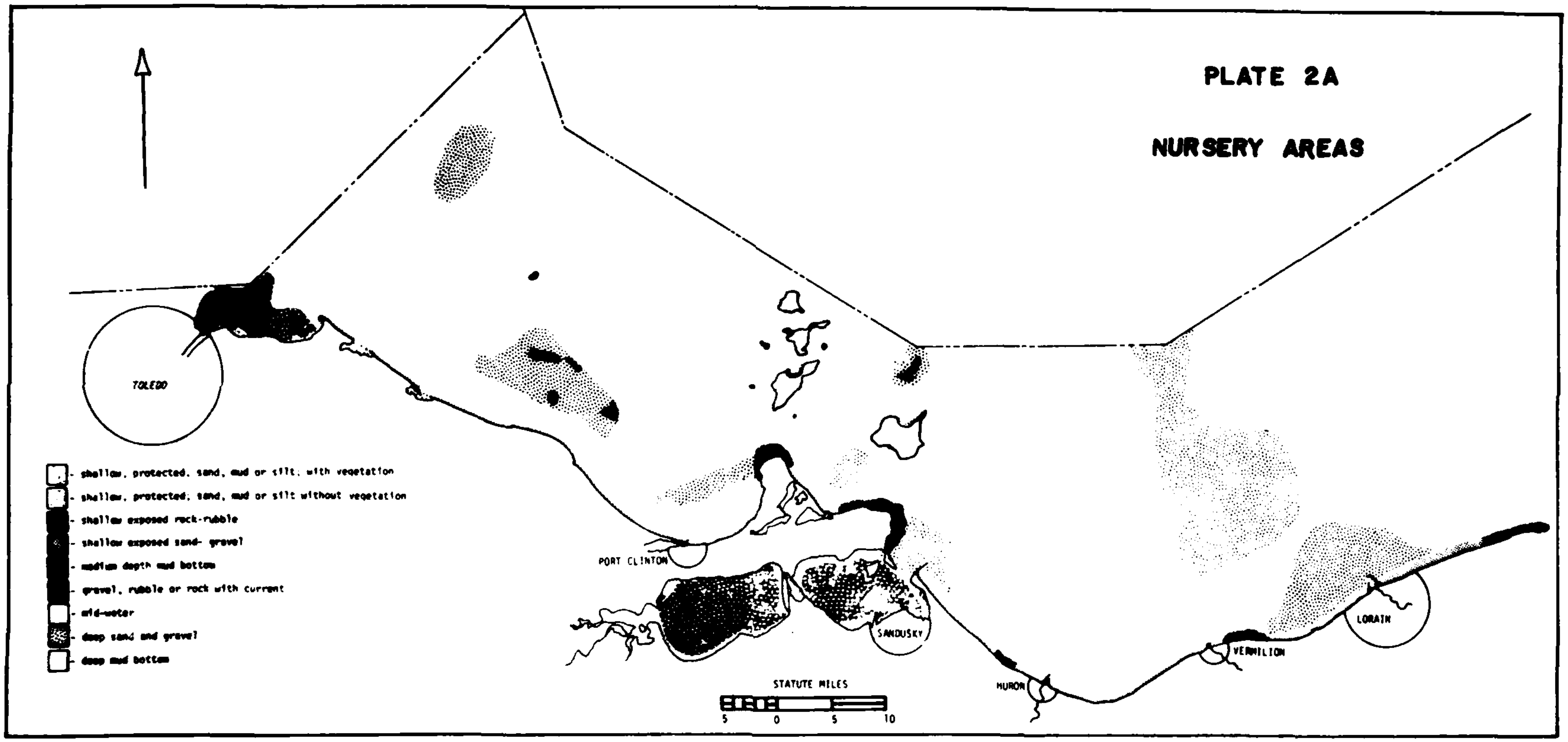


Figure **F-39** **Major Nursery Areas in Lake Erie's Western and Central Basins**

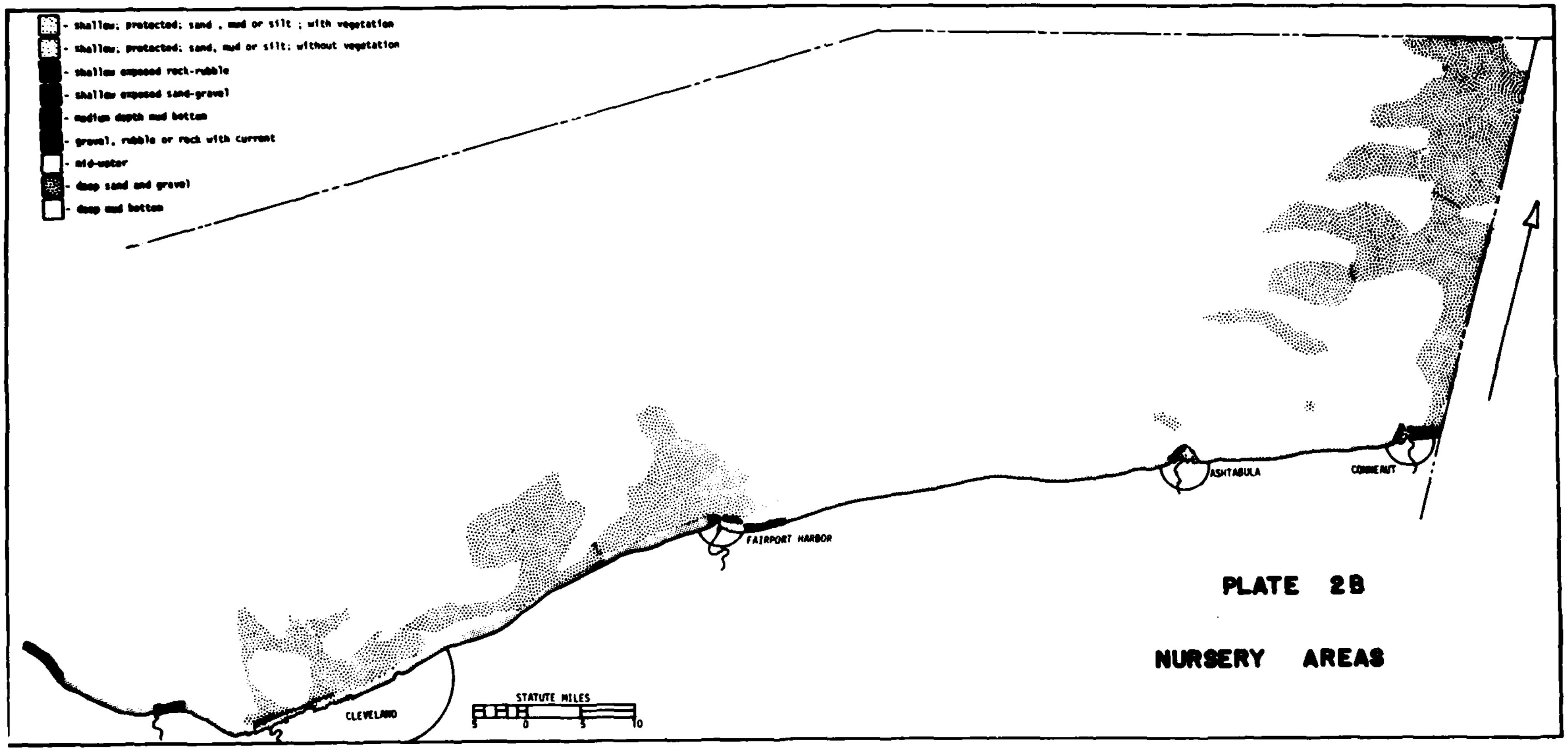


Figure F-40 **Major Nursery Areas in Lake Erie's Central Basin**

Table F-45

Important Resource Areas in Lake Erie's Central Basin

Area Name	Important Characteristics and Remarks
Rondeau Bay (Canada)	extensive marsh areas; sensitive to water-level changes; warmwater spawning and nursery.
Catfish Creek (Canada)	rainbow trout spawning runs.
Big Otter Creek (Canada)	rainbow trout, coho salmon, chinook salman spawning.
Clear Creek (Canada)	rainbow trout spawning runs.
Huron River System (US)	marshes and open water; principal river for coho salmon.
Black River-Lorain Harbor (US)	237,400 fish taken in 1976 by anglers.
Cuyahoga River (US)	locally important commercial fishery.
Ashtabula River (US)	locally important commercial fishery.
Conneaut Creek (US)	stocked with steelhead trout.

The important areas and wetlands of the eastern basin are summarized on Table F-46. Of these areas, Long Point Bay is probably the most important. The area around Long Point is managed primarily as a sport fishery, with the shallow Inner Bay supporting a limited commercial fishing industry. In the deeper offshore waters an important gill net and trawl fishery also exists. Long Point Bay provides spawning, nursery, and feeding areas for many fish species including smallmouth bass, rock bass and northern pike.

A 1977 angling survey by Reid (1978) showed a harvest in Long Point Bay from May 1 to June 17 of 42,596 fish, composed of 42 percent yellow perch, 36 percent rock bass, 6 percent smallmouth bass, 4 percent northern pike, 4 percent panfish, and 8 percent other species. In 1973, the summer open water sport fishery in Long Point Bay was valued at close to 4 million dollars (Melski 1973), and the winter ice fishery was valued at 1.1 million dollars.

Presque Isle Bay (which is on the central-eastern basin boundary) and the adjacent areas east of Erie, Pennsylvania, provide excellent habitat for a wide variety of fish species. The New York waters of Lake Erie were the top sport fishing area for all waters in New York State. Yellow perch, walleye, smallmouth bass, coho salmon, brown trout, and rainbow trout are the major fish taken in these areas. There appears to be an emerging lake trout fishery developing also.

5.3.4 Niagara River

The Niagara River is the natural outlet of Lake Erie and flows north to Lake Ontario with Niagara Falls dividing the river into almost equal upper and lower portions. The river has a general trough-like topography with steep banks, a bedrock bottom, and few shallow water embayments.

The inshore waters of the extreme eastern end of Lake Erie and the Upper Niagara River support a recreational fishery composed principally of smallmouth bass, yellow perch, muskellunge, northern pike and salmon. The smallmouth bass fishery extends along the Lake Erie shore and throughout the Niagara River, while the muskellunge and northern pike fishery is mainly in the river itself. The nearshore waters of the Upper Niagara River also support a bait fishery which is a major local economic value.

Species recorded in the Niagara River and its tributaries are presented in Annex 8. A total of 91 species of fish, comprising 55 genera and 24 families, have been identified for the river system. This illustrates the diversity of the river's fish community.

Smallmouth bass are known to spawn in the Niagara River and its inflowing creeks. O'Mara (1977) found major spawning grounds in three regions of the upper river around Beaver Island in the shallow south beach area, around Navy Island in both shallow and deeper waters, on the shallow nearshore plain on the West Grand Island shoreline opposite Navy Island.

Table F-46

Important Resource Areas in Lake Erie's Eastern Basin

Area Name	Important Characteristics and Remarks
Lynn River, Grand River, (Canada) Bay Creek, Potters Creek, Fishers Creek, Lawrence Creek, Youngs Creek	coldwater species: rainbow trout, brown trout, and chinook coho salmon use these streams.
Long Point Bay (Canada)	extensive wetlands and spawning areas.
Fort Erie Shoreline (Canada)	extensive area of smallmouth bass.
Cattaragus Creek (U.S.)	spawning habitat; some marsh habitat.
Presque Isle Bay (U.S.)	important warmwater fish spawning areas and salmonid area.

Little detailed work has been done on the Upper Niagara muskellunge population, however, the primary spawning grounds are thought to be located in an area bounded by Strawberry Island, Motor Island, and the southern tip of Grand Island. Harrison (1978) also identified two secondary spawning grounds located in the waters between Navy and Grand Islands and in the Tonawanda Channel near the mouth of Woods Creek

The spawning habits of Niagara muskellunge differ considerably from other muskellunge populations. Harrison (1978) reports that Upper Niagara muskellunge spawn in waters 3-6 feet in depth compared to the 1 - 2 foot reported by Scott and Crossman (1973) as the preferred depth for this species. Harrison (1978) also reported that the Upper Niagara River muskellunge spawn at a higher water temperature than generally reported in the literature. The Niagara River muskellunge also seem to spawn in areas where there is a current as opposed to most other muskie populations.

The Niagara River muskellunge exhibit habitat preferences which confine the populations to a very small portion of the river. In addition, typical spawning behavior shows how well adapted the muskellunge are to the present environmental conditions of the river. Sudden changes in the river environment could adversely affect this population.

The shallow marsh and heavily vegetated areas within the creeks flowing into the Niagara River are utilized by northern pike, carp, suckers, and walleye. Walleye also spawn on the shoals of the eastern basin near the headwaters of the Niagara River.

In addition to the above-mentioned warm water fishery, there is also a cold water fishery on the Upper Niagara River. This is not a native fishery, but has resulted from the Lake Erie salmonid stocking program. The species that now inhabit the area are brown and rainbow trout, coho and chinook salmon.

The Niagara River bait fish industry is valuable to the local economy. The majority of the Canadian bait fish harvested are sold wholesale to other dealers; some are exported to the United States. The emerald shiner is the most valuable bait fish of the Niagara River. Mudminnow, a juvenile white sucker, and spottail and golden shiner are also actively sought. The Upper Niagara River provides a major regional source of bait fish. From 1973 to 1976 the Upper Niagara River averaged 368,438 dozen bait fish per kilometer of harvestable shoreline (Buckingham et al., 1977).

5.3.5 Lake Ontario

Description of General Area:

Lake Ontario is a deep, coldwater lake of relatively low productivity. The inshore zones of the western and eastern basins of Lake Ontario are characterized by steep slopes making the productive shallow-water margins small. The eastern outlet has numerous islands and

shoals providing excellent habitat for both shallow and deep water species (Christie 1972).

Historically, the Canadian waters of Lake Ontario supported a valuable coldwater commercial fishery based on lake trout, whitefish, and ciscoes. Overfishing, habitat alteration, and invasion by alien species has led to the decline of these stocks (Christie 1972). Therefore, the commercial fishery on Lake Ontario is now concentrated in the shallow eastern outlet basin and is dependent on warm-water species.

Sport fishing activity on Lake Ontario is mainly in the shallow eastern outlet basin, particularly the waters fronting Prince Edward County, Ontario, and surrounding Amherst and Wolfe Islands (Kolenosky 1977). Since the late 1960's, when the salmonid plantings started to take hold, a cold-water fishery has been developing on Lake Ontario. This fishery is centered along the extreme western basin shoreline.

The fish community of the offshore waters of Lake Ontario is composed almost entirely of smelt, alewives, and slimy sculpins (Larsen and O'Gorman 1972). Alewives are found lake-wide while smelt are more numerous in the western basin and slimy sculpins dominate the southeastern region. Smelt are abundant enough in the western basin of Lake Ontario to sustain a commercial trawl fishery (Thurston 1969).

The nearshore waters of Lake Ontario support a more diverse population than the offshore waters (Hartman et al., 1972). Yellow perch, smallmouth bass, pumpkinseed, rock bass, brown bullhead, and alewife are all classified as "abundant" in the nearshore zone and 14 other species are termed "common" (see Annex 8). It should be pointed out, except for alewives, most of these warm water species are concentrated in the shallow eastern outlet basin. The abundance of these species is greatly limited in the western and central basins by the lack of suitable habitat.

The total value of the Lake Ontario-St. Lawrence River sports fishery has never been estimated in detail. Studies of selected portions of the fishing area have been utilized to estimate the value of various fishing derbies, financial impact of salmon and trout of the Salmon River area, and value of the smallmouth bass fishery at the eastern end of Lake Ontario and St. Lawrence River. Utilizing the known fishery value information and greel census information on fisherman use, it was estimated that the lake and river fishery is presently valued at between 15 and 25 million dollars. This figure is expected to rise over the next 10 years as the fishery for lake front, brown front, rainbow-steelhead, coho salmon, chinook salmon, and atlantic salmon is more fully realized. The change in the fishery is due to management decisions, which have included support for modern state and federal hatcheries, and for updated fishing regulations for cold and warm-water fish. These initiatives are expected to produce a 100 million dollar fishery in New York waters alone.

There are a number of tributary streams, bays, and wetlands on Lake Ontario which may be affected by water level changes. These are listed in Table F-47.

TABLE F-47

Major Ecological Sensitive Areas Along Shoreline of Lake Ontario

U.S. Shoreline of Lake Ontario

Area	Remarks and Characteristics
Four Mile and Six Mile Creek	Gravel barrier beach at mouth, little flow into the lake except at high periods.
Twelve Mile Creek	Major fishery resource: trout, coho salmon, bulkhead, crappie, bass and yellow perch.
Eighteen Mile Creek	Important smallmouth bass spawning stream.
Johnson Creek	Fall runs of coho and chinook salmon.
Oak Orchard Creek	Smallmouth bass spawning area.
Sandy Creek	Mouth is shallow embayment-wetland.
Braddock Bay	Important for bass, northern pike, walleye, perch, bullhead, crappie and sunfish.
Cranberry and Long Ponds	Important wetlands and spawning areas for pike, bass, walleye, pickerel and panfish.
Round Pond	Fed by Round Pond Creek and separated from the lake by barrier beach.
Irondequoit Bay	Large polluted bay with small outlet to lake.
Salmon Creek Maxwell Bay	Important natural trout reproduction
Great Sodus Bay	Federal harbor; good warmwater fishery; has lotus beds (unusual plan species in New York).
East Bay, Port Bay, Red Creek, Blind Sodus Bay	Usually separated from the lake by barrier beach except during high water.
Little Sodus Bay	Commercial and Federally maintained harbor.

Table F-47 (Continued)

Snake Creek Swamp, Rice Creek, Wine Creek, Teal Marsh Otter Branch Creek	Wetlands separated by barrier beaches.
Butterfly Swamp	Extensive wetland separated by barrier.
Little Salmon River, Grindstone Creek	Class 1 salmonid stream along with smallmouth bass, walleye and perch.
Deer Creek Wetland	1,300 acres of productive wetland, northern pike spawing area.
Cranberry Pond, Sandy Creek Marsh Lakeview Point, Southwick Beach, Black Pond Marsh, Little Stoney Creek, Ray Bay Marsh, Campbell Marsh, Point Pensula North Marsh, Wilson Bay Marsh, Fuller Bay Marsh	All are protected flood ponds and important wetland areas. Important salmonid and warm-water fishery areas.

Canadian shoreline of Lake Ontario

Area	Remarks and Characteristics
Shoreline between Hamilton and Mississauga	Heaviest angling pressure of entire lake especially for salmonids (coho salmon).
Wimot Creek, Ganaraska River	Salmonid area especially rainbow trout.
Bay of Quinte	Warmwater fishery.
Wolfe and Howle Island	Smallmouth bass, yellow perch and northern pike.

5.3.6 St. Lawrence River

The St. Lawrence River comprises a large and complex ecosystem. It is composed of deep water, islands, shoals, littoral edge, wetlands, and adjacent uplands linked together by the constancy of river flow and the movements of species in an integrated series of aquatic and terrestrial-riverine food webs. The ecosystem is driven by inputs of phytoplankton, zooplankton and fish from Lake Ontario, coupled with detrital energy sources of an undetermined character from wetlands, the littoral zone, and surrounding uplands. Water level and flow changes represent a critical forcing function through the influence they exert on the production of these energy sources particularly in wetlands. The character of the ecosystem varies from point-to-point along the shoreline and from season-to-season during the year.

The primary source of Planktonic organisms is Lake Ontario, and there is a progressive decrease in standing crop biomass groups from Lake Ontario to the international boundary. Phytoplankton turnover is rapid, and the addition of significant levels of zooplankton from inshore sources is hypothesized. Benthic communities vary significantly with bottom conditions, but amphipods, tubificids, and chironomids represent important groups across all bottom types (NYSDEC and State Univesrsity of New York, Technical Reports B, K, and L, 1978).

Fish literature surveys from the 1930's to the present suggest that a total of 120 fish species may be found in the St. Lawrence River watershed (Eckert and Hanlon 1976). Eleven major warm-water species have been identified as important in the river. These are smallmouth bass, northern pike, yellow perch, brown bullhead, muskellunge, rock bass, white perch, white bass, pumpkinseed, largemouth bass, and walleye. Other species are intimately linked to resource vitality through the foraging preference of the large species. Substantial differences in fish community composition occur from point-to-point along the shoreline, and from time-to-time as a result of fish movements (NYSDEC and State University of New York, Technical Report D, 1978).

For the purpose of the present study, the St. Lawrence River was divided into the following subsections: Upper St. Lawrence - Thousand Islands; Whitney Point-Iroquois; Lake St. Lawrence and Lake St. Francis.

Upper St. Lawrence River-Thousand Islands:

This stretch of river is characterized by broad expanses of slow-flowing water dotted with numerous large and small islands. The upstream third of this section has relatively large amounts of open, deep water, whereas the downstream two-thirds contains many shoals, much littoral zone, and many sheltered bays.

Angling is an important attraction of the Thousand Islands area which is noted for its recreational opportunities.

Many sensitive areas of importance to the fish community have been identified in this section of the river as shown on Table F-48. However, any creek mouth in this area could be included as important fish spawning/nursery areas.

Mid-section: Whitney Pt.-Iroquois:

This stretch of river is narrow and deep with limited littoral zone, few embayments and relatively few islands. The lower half has been greatly altered by the St. Lawrence Seaway Project. Comparatively little fishing, either recreational or commercial occurs and, consequently, fewer fishery investigations have been conducted in this area. The mouth of Johnstown Creek has been identified as a sensitive area for pike and bass spawning (OMNR Eastern Region, unpublished report).

Lake St. Lawrence:

The St. Lawrence River between the Iroquois Lock and the Moses Saunders power dam has been drastically altered by flooding caused by the latter structure resulting in Lake St. Lawrence. The formation of Lake St. Lawrence eliminated many of the original features of the river and caused profound changes in the aquatic community. Unfortunately the lack of detailed information on pre-project conditions of the fishery makes it difficult to describe the changes precisely. Following the formation of the lake, the abundance of walleye declined markedly and has never recovered. For a few years the abundance of northern pike, smallmouth bass, and largemouth bass increased. Following 1962, however, pike declined in abundance while yellow perch and panfish increased. The bass species have shown no strong trends in abundance. "Coarse" fish, including carp, sucker and bullhead, are common (OMNR Eastern Region, unpublished report). The changes in the fish population following the creation of Lake St. Lawrence appear to closely parallel the growth and decline of aquatic macrophytes which in turn reflect trends in the primary productivity of these waters.

Due to the ready access to the shore provided by the many parks along Lake St. Lawrence, angling pressure is moderately heavy. There is also some commercial netting carried on, principally for "coarse" species and panfish. Fluctuations of water level amounting to 6 to 12 inches occur almost daily, due to operations at Moses Saunders Dam (Swee and McCrimmon 1966). These fluctuations are believed to cause massive mortalities of carp eggs in the spring.

A number of sensitive areas have been identified in Lake St. Lawrence (OMNR Eastern Region, unpublished reports). They are listed in Table F-49.

Lake St. Francis: Cornwall to the Ontario-Quebec Border:

Only the Ontario section of this lake is considered here. Between Cornwall and Summerstown, Ontario, several large islands divide the river flow into separate channels. Except in the shipping channel, much of Lake St. Francis is less than 10 feet deep. Water levels are

Table F-48

Important resource areas between the Upper St. Lawrence River and Thousand Islands on the Ontario side of the river (from unpublished data: OMNR, Eastern Region)

LOCATION	COMMENTS
Lewis Bay (Wolfe I.)	Pike spawning area
Bayfield Bay (Wolfe I.)	Smallmouth bass and pike spawning; commercial fishing
Button Bay (Wolfe I.)	Pike spawning; commercial fishing
Big Sandy Bay (Wolfe I.)	Smallmouth bass spawning
Reed's Bay (Wolfe I.)	Pike and smallmouth bass spawning; commercial fishing
Channel to Mill Pt. (Wolfe I.)	Smallmouth bass spawning
Garden I.	Smallmouth bass spawning; commercial fishing
Barrett Bay (Wolfe I.)	Pike and smallmouth bass spawning
Brown's Bay (Wolfe I.)	Pike and smallmouth bass spawning
Knapp Pt. to Beauvais Pt. (Wolfe I.)	Smallmouth bass and pike spawning; commercial fishing
Moores Creek (Treasure I.)	Pike spawning
Grass Creek Pt. (Bateaux Chnl.)	Pike spawning
Johnson Bay (Howe I.)	Pike spawning; commercial fishing around island
Gander Cr. mouth (Bateaux Chnl.)	Pike and largemouth bass nursery area
Melville I. eastside	Pike and smallmouth bass spawning; commercial fishing
Stave Island	Muskellunge spawning
Holsted Bay	Bass spawning

Table F-48 (Continued)

Landon Bay	Pike, bass and muskellunge spawning; commercial fishing
Shipman's Point wetland	Pike and largemouth bass spawning; commercial fishing
LaRue Mills to Rockport	Smallmouth bass spawning
N. Shore Grenadier I.	Muskellunge spawning
River Front of Yonge Tnsp.	Smallmouth bass spawning
Hill I.: wetlands of east and west ends	Pike and largemouth bass spawning; angling

Table F-49

Ecologically Sensitive Areas in the Lake St. Lawrence Section of the St. Lawrence River (from unpublished data: OMNR, Eastern Region)

LOCATION	COMMENTS
Pinetree Point	Bass fishing in two bays east of the point
Flagg Bay	Bass and bullhead fishing
Hoasic Creek	Possible walleye spawning area; bass, pike and crappie fishing
Riverside Prov. Park	Pike spawning in wetland
Battlefield Park	Pike spawning in Marina Bay
St. Lawrence Parks (5 shores of Ault, Nain and Mossison Is.)	Yellow perch and bullhead spawning and fishing
St. Lawrence Parks (bird sanctuary)	Pike spawning in marsh
Between West Woodlands I. and Mainland	Bass spawning
Houple Creek Bay	Crappie and pike spawning; possibly walleye spawning
Between East Woodlands I. and Wales I.	Muskellunge spawning
Sheek I.	Bass spawning on N. side
Strachan I.	Bass spawning

affected by the regulation of inflows at the Moss-Saunders Powerhouse upstream, and by discharge through the Beauharnois control and power dams downstream. Fluctuations in stage, however, are generally held to less than 2 or 3 feet annually (Ontario Ministry of the Environment 1975).

Both summer and winter angling, and commercial fishing, are practiced in Lake St. Francis. Greel censuses conducted by OMNR indicate that the principal sport fish is yellow perch, with northern pike a distant second. Small numbers of smallmouth bass and walleye are also caught. The commercial fishery is directed mainly toward bullhead, sunfish, eel and carp. Containment levels in recent years have affected the commercial catches of several species.

5.4 Evaluation Of Systemic Effect Of Regulation

5.4.1 Areas and Species Sensitive to Lake Level Changes - General Overview

A lake is not a single habitat where aquatic life is evenly distributed over the total area. It is rather a mosaic of different habitats or sub-habitats with various aquatic organisms exerting distinct preferences. This segregation by habitat is one of the most important ways aquatic organisms partition the limited resources available to them (Keast 1978).

Fig. F-41 shows a sterotypic profile of a lake. The land-water interface in open areas is normally devoid of any vegetative growth down to depths of 11.5 feet (Emery 1973). In this region waves hinder macrophyte substrate attachment in the summer, and in the winter ice scours the bottom further reducing any chance of vegetative growth. For the open shoreline, it is in the deeper water that macrophytes, invertebrates and fish begin to flourish. These deeper areas would seemingly be unaffected by lake level changes of the magnitude being considered in this study. However, the use by fish of offshore reefs and shoals such as those found in western Lake Erie may be impacted. Some of these reefs are very important spawning areas but only the area of the reef or shoal which is within the desired depth range is used by the specific fish species.

In sheltered bays and inlets aquatic life exists to within a few centimeters of the shore. In these protected areas a totally different assemblage of aquatic life exists. Emergent plants exist close to shore followed by the floating plants and finally by the submergents.

Contemporary studies on the ecology of fish communities have emphasized resource partitioning among co-existing fish species (Keast 1978, Hall and Werner 1977). These studies have shown that different habitats generally support characteristic fish species assemblages. This spatial(habitat) segregation of fish species has been demonstrated to be dependent upon factors such as bottom type, vegetation, water depth, and water quality.

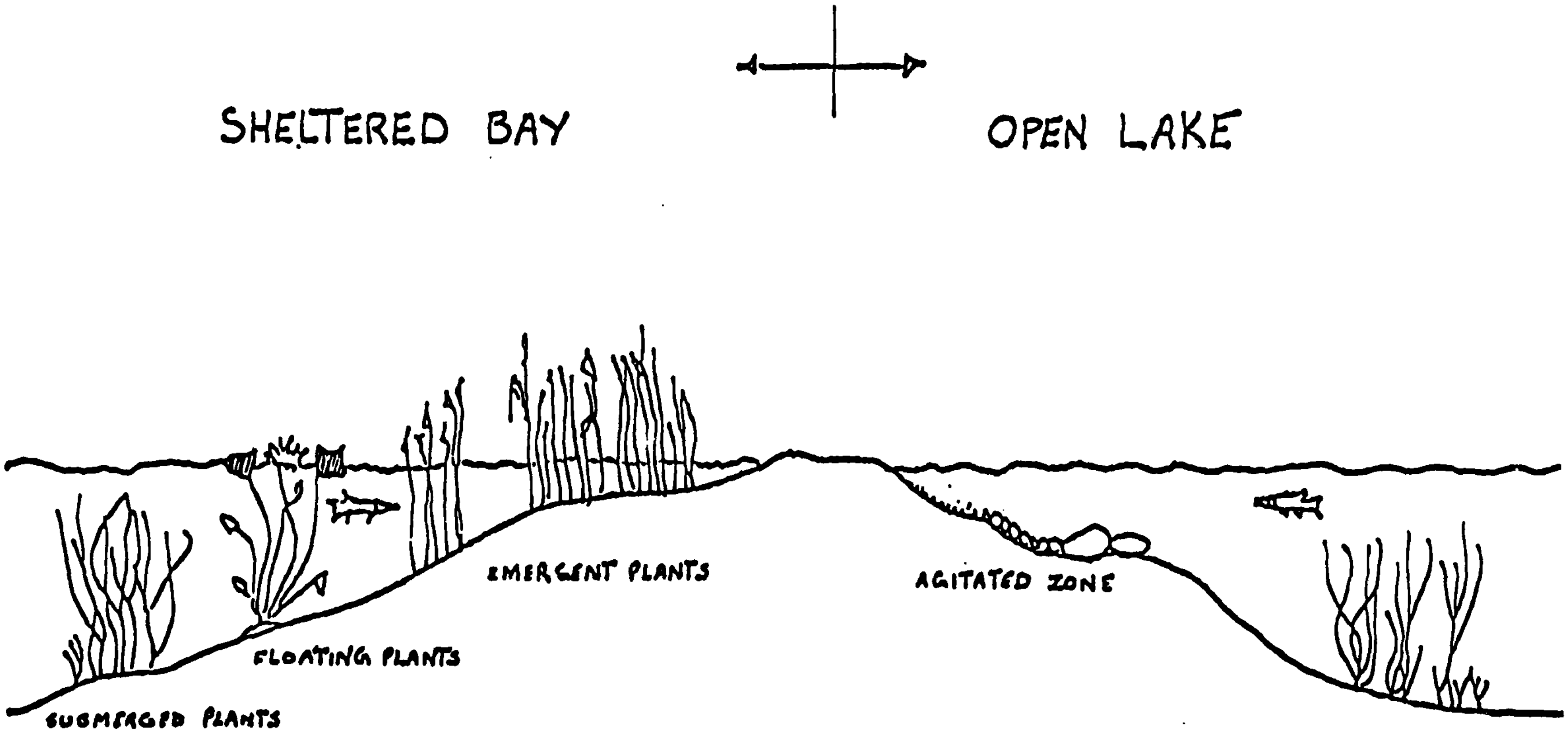


Fig. 41 Stereotypic profile of sheltered bay and open lake shorelines.

The fact that fish do show habitat specialization is important in the context of this study. If lake level regulation destroys or alters any of these preferred or essential habitats the deleterious effects on the fish community could be very drastic. Habitat destruction or modification is a contributing factor for 98 percent of the fish species listed by the American Fisheries Society as endangered, threatened, or of special concern (Deacon et al. 1979). Panek (1979) considers the piecemeal loss of spawning and nursery areas as one of the greatest threats to North American fisheries.

A list of preferred fish habitat types developed by Hartley and Van Vooren (1979) for western basin Lake Erie fish is presented in Annex 8. These data help to illustrate the extent to which fish are associated with different habitat types and show the distributional differences with life stage, season, and activity. In addition, the data illustrate the importance of the nearshore zone to fish productivity. For a small lake in Ontario, Keast and Harker (1977) found that 90 percent of the fish biomass and 68 percent of the invertebrate biomass occur within a region that parallels the shore at a depth of less than 8.2 feet.

5.4.2 Importance of Water Level Fluctuations on Fish

Water levels and their fluctuations are biologically important, however, very little work has been carried out to determine their significance to fish populations of the Great Lakes. Beeton and Rosenburg (1968) suggested that on the Great Lakes, increases in water levels would be beneficial to the fish population because higher levels would provide more favorable fish habitats. Decreases in water levels would be unfavorable due to their impacts on spawning and feeding areas. This is the same general conclusion reached by the International Great Lakes Level Board (IGLLB 1973).

Higher than normal water levels have been associated with larger year classes of walleye and pikeperch for several water bodies. These results have been reported for reservoirs on the Missouri River (Nelson and Walburg 1977), for some Swedish lakes (Svardson and Molin 1973), and for some lakes with major marsh areas such as Clear Lake, Iowa (Carlander and Payne 1977), and Lake Winnebago, Wisconsin (Priegel 1970).

The influence of various spring water levels on year-class strength of some western Lake Erie fish has been evaluated. The premise was that if a relationship between various historic spring water levels and the abundance of various young-of-the-year fishes could be identified, then this information might be applicable to regulation evaluation.

Data on the abundance of young-of-the-year fishes in western Lake Erie have been collected since 1959 by the U.S. Fish and Wildlife Service, Sandusky, Ohio. The data were obtained through systematic bottom trawling at six index stations from June 15 to November 15 each year. The abundance is calculated as the average number of young-of-the-year fish captured per hour of trawling. The abundance index provides a good indicator of year-class strength as determined from

cohort analysis of commercial harvested fish (W. L. Hartman and H. D. Van Meter, pers. communication). Busch and Brown (unpublished data) compared the annual abundance index of 11 species of fish with the average April 1-June 30 Lake Erie water levels for the years 1959 to 1974. A range of correlation coefficients of +0.71 to -0.53 were obtained from linear regressions (Table F-50). Six of the eleven comparisons produced significant correlations. The results indicate that some fish species produce stronger year-classes during low water years, other species produce stronger year-classes during high water water years and some species are apparently not affected.

The stresses or benefits produced by various water levels on alewife, smelt, gizzard shad and trout perch, the species with the strongest water level/year-class size correlation, are not clearly understood. Further evaulation would require detailed data concerning the life history of these species in western Lake Erie. These data are not available.

It must be made clear that for these comparisons, only water level fluctuations were considered to cause year-class size variations. It ignores other environmental stresses and assumes that the broodstock and/or egg production were the same each year. Busch et al. (1980) found in a detailed analysis of the life history of yellow perch from western Lake Erie that even though water level fluctuations appeared to influence year-class size, this stress became less significant when other environmental factors (water temperature and winds during spawning/incubation periods) were included in the analysis. Also, Busch et al. (1975) reported that the historic water fluctuations in western Lake Erie had no apparent impact on the fluctuations in the size of the walleye year-classes. Johnston (1977) reached the same conclusions concerning the Lake St. Clair walleye.

Chevalier (1977), demonstrated that the spring water level is one of the factors determining Rainy Lake walleye abundance. He compared annual walleye commercial catch per unit effort (CUE) with spring water levels, 4, 5, and 6 years earlier and found positive correlation coefficients of 0.48, 0.71, and 0.47, respectively. Multiple linear regression analysis of the spring water level 5-years earlier than the CUE showed that 50 percent of the variation in the commercial catch could be attributed to spring water levels.

Whillans (1977) suggested that water levels in combination with related macrophytes, water quality and bathymetric conditions played a significant role in the nearshore fish community transformations in Long Point Bay. Species he lists as probably being affected by these factors are bowfin, alewive, gizzard shad, northern pike, white sucker, brown bullhead, channel catfish, rock bass, pumpkinseed, black crappie, largemouth bass, and yellow perch.

In recent years water level manipulations have been used in water storage reservoirs to the benefit of their fish population (Groen and Schroeder 1978, Nelson and Walburg 1977). Although these situations usually deal with large changes in water levels, they do illustrate how

Table F-50

Comparison of the Young-of-the-Year Abundance[1] of Western Lake Erie Fishes with the April-June Water Level, 1959-1974

Species	Correlation Coefficient[2]	Level of Significance
Alewife	+0.71	P 0.01
Smelt	+0.67	P 0.01
Gizzard Shad	+0.63	P 0.01
Walleye	+0.40	P 0.20
White Bass	+0.25	NS
Freshwater Drum	-0.03	NS
Spottail Shiner	-0.20	NS
Channel Catfish	-0.22	NS
Emerald Shiner	-0.31	NS
Yellow Perch	-0.40	P 0.20
Trout Perch	-0.53	P 0.05

[1]Abundance calculated as the average number of YOY fish captured by systematic bottom trawling from 15 June through 15 November each year (unpublished U.S. Fish and Wildlife Service, Sandusky, OH 44870).

[2]Obtained from linear regressions.

water levels can affect fish productivity. Generally, upon the initial filling of a reservoir the fish productivity increases, reaches a peak, and then decreases to a much lower level. This sequence of events has been attributed to the inundation, decline, and eventual decomposition of the newly flooded shoreline vegetation (Nelson 1978, Shirley and Andrews 1977). Species of fish that have been shown to be sensitive to reservoir water level fluctuations, particularly during their respective spring spawning period, are largemouth bass (Shirley and Andrews 1977), yellow perch (Nelson and Walburg 1977), walleye (Groen and Schroeder 1978), and northern pike (Goddard and Redmond 1978). For all these species strong year-classes were associated with inundation of terrestrial vegetation during spawning.

Water level fluctuations are important to a wetland's ecology Section 4. At least five factors are critical in determining plant response to changes in water level: time of year, flood frequency, flood duration, water depth, and siltation. Other mechanical factors, such as wave action and erosion of soil from around roots, cause detrimental effects during flooding. Water level fluctuations rejuvenate the wetlands and prevent them from becoming chocked with vegetation.

These same conditions provide many benefits to nearshore fish communities. Fluctuations keep channels open into the wetlands providing fish access to food and shelter. These channels also prevent stagnation and oxygen depletion by permitting the easy inflow of fresh water. In addition, the nutrients released into the open lake increase primary productivity and, therefore, indirectly increase fish production.

Another important ecological feature of the annual water level cycle is the low water period (generally from November to March). Emery (1973) showed that various fish species reinvade the nearshore zone, particularly vegetated areas, once the ice cover forms. Low water levels in winter if lowered could reduce the availability of this habitat; increase bottom scouring by the ice; probably increase the amount of aquatic vegetation uprooted by ice movements; decrease oxygen content; and trap the fish under the ice in shallow water areas.

5.4.3 Implications and Significance of Particular Water Level Parameters

All regulation plans have the potential to adversely affect some of the fish populations. The effects may be insignificant or very significant depending on the magnitude and direction of the lake level changes and the sensitivity of the area and/or species to the changes.

Based on analysis of the historical water level pattern and the review of the literature, the water level parameters identified as important to the maintenance and development of the existing fisheries resource were seasonal occurrence of annual low water level, rate of increase in spring water levels, seasonal occurrence and duration of annual high water level, long-term mean water level, extreme high and low levels and annual high-low water range.

The historical occurrence of the annual low water level generally in December, January, or February, sets the stage for favorable conditions in the spring. Artificially lowered water levels during this period would reduce the already limited habitat available to the many species that reinvade the nearshore zone once the ice cover forms. The increased bottom scouring and uprooting of aquatic vegetation caused by ice could adversely affect the nearshore fish stocks.

Water level increases during the winter could result in flooding of the wetland snow and ice cover by bleeding water through the hinge crack. For example, water entering a wetland system in this way would modify the ice and snow pack character of the wetlands. Such modifications could significantly alter the nature of the winter wetland condition by freezing and destroying surface benthic organisms and by creating additional cracks and instabilities which could result in breakup of the emergent wetland mat during the spring. In addition, wetting the ice surface along the hinge crack would increase the snow-ice depth and extend the freeze-down zone further outward into the water. This effect would magnify a natural disturbance process which occurs at the open-water wetland interface during spring breakup.

The rise of water levels in the spring increases the availability of aquatic habitat thereby reducing competition for essential living areas (spawning, nesting, nursery, feeding, etc.). The timing of this rise is critical, especially for species such as northern pike and golden shiner, which are dependent on plants for spawning. The rising levels also enhance nutrient releases thereby increasing primary productivity and indirectly increasing fish production.

Seasonal occurrence and duration of annual high water level during the summer should be maintained. The high levels increase the availability of aquatic habitat, maintain favorable spawning and nursery conditions, and reduce competiton for limited resources such as space and food.

The amplitude of the seasonal water level fluctuations is important to the nearshore wetlands ecology (See Section 4). These fluctuations rejuvenate the wetlands each year and prevent them from becoming choked with vegetation. These same conditions provide many benefits to nearshore fish communities. Fluctuating water levels keep the channels open into the wetlands providing fish with access to food and shelter. These channels also prevent wetland stagnation and oxygen depletion by permitting inflow of fresh water, and allow the passage of nutrients into the open-lake increasing primary productivity, thus indirectly aiding fish production.

Lowering the long-term mean water level could cause a hydric to mesic plant community succession in shoreline wetlands. This could result in a permanent loss or impairment of nearshore spawning grounds and/or nursery areas. Leafy hydric macrophytes are more densely populated with invertebrate forage organisms than the mesic emergent macrophytes. Lower lake levels most likely would reduce the availability of certain food sources by creating larger areas of emergents and less area in submerged plants.

Lowered long-term mean levels could also cause changes in the thermal regime of the shallow protected embayments (e.g., Rondeau Bay, Long Point Bay and parts of Sandusky Bay). The thermal changes may adversely affect the reproductive success and growth rates of the fish species utilizing these areas.

The historical frequency of occurrence and duration of extreme high and low level periods is important, particularly for the extreme lows. Any lowering of the extreme lows would reduce the availability of already limited shallow water habitat. Also, the lowering of extreme low levels may result in increased wetland diking, thereby permanently removing additional wetland areas (See Section 4) as fish habitat.

The long-term (historical) range of fluctuations should be maintained. These fluctuations maintain the diversity of the wetlands by not allowing plant succession. High water periods for 3-5 years duration open the marsh by causing die-offs of dense emergent and sedge vegetation and an invasion by open-water, submergent, and floating-leaved plants. Low periods enhance the growth of emergents and sedges. High waters allow fish to enter the wetland and the submergent and floating-leaved plants are more productive fish habitat.

A reduced range would encourage a more homogeneous vegetation community to develop which, if the range were reduced sufficiently, would revert to a mesophytic and eventually upland environment which would result in lost fish habitat.

5.4.4 Effects of Regulation

The effects on fish of the relatively small changes in lake levels resulting from the regulation plans seem negligible. However, it should be remembered that the plans call for a permanent lowering of the water level on Lake Erie and the upper lakes resulting in changes or losses in aquatic habibat. This would be most noticeable in the highly productive nearshore waters, particularly in areas of gentle slope and in the connecting channels. Wetlands, which are important spawning, nursery, and feeding areas for many fish species, would show the greatest impact. As shown in Table F-50., low historic water levels (short-term) favoured trout perch at the expense of alewife, smelt and gizzard shad. These fishes are an important part of the forage base used by the stocked salmonids. Major decreases in the abundance of the forage fish would have a negative impact on the abundance of predation species.

Long-term lowering of Lake Erie water levels would cause a permanent displacement, impairment or loss of "essential living areas" such as spawning grounds, nursery and/or feeding areas. These areas, relative to physical features (e.g., depth contours, shoals, embayments, etc.), could reestablish themselves lakeward; however, the extent or rate of this potential replacement is not known. It may not take place at all. Beeton and Rosenburg (1968) state that reestablishment of wetlands lakeward during periods of low water usually does not occur due to exposure to waves and currents. In addition, Jaworski et al. (1979) show that lakeward migration of wetlands is dependent upon substrate

suitability, thereby further limiting potential for habitat reestablishment. Since no two areas are the same, evaluation of such effects such should be site-specific.

Alterations in the seasonal pattern of water level fluctuations could cause impacts of varying severity depending on their amplitude, frequency, duration and seasonal occurrence. Both inundation and de-watering could result in impairment to aquatic flora and fauna, with particular impact on egg and early life stages of various fish species.

Alterations in the pattern and velocity of water flow, especially in confined waterways and connecting channels, has the potential of severely impacting localized fish popultions. The suspension and redeposition of suspended solids; changes in the distribution of dissolved oxygen, nutrients, and contaminants; changes in water temperature; and the loss through erosion or burying of important bottom materials are some of the potential hazards the fish populations of the connecting waters may face with lake level regulation.

Jaworski et al. (1979) indicate that the density of emergent vegetation increases at the expense of submergent vegetation during low water years. Leafy submerged macrophytes are more densely populated with invertebrate forage organisms than emergent vegetation (Krecker 1939). Lower lake levels could reduce the availability of certain food sources to fish through a decrease in vegetation which supports the growth of invertebrates.

Lakes St. Clair and Erie:

In the long term, the lowering of lake Erie and Lake St. Clair water levels by Plan 25N would appear to have the potential to cause a permanent displacement, impairment or loss of "essential living areas" such as spawning grounds, nursery areas, and/or feeding areas within the nearshore zone. The effects on fish of water level changes due to Plans 6L and 15S are much more difficult to evaluate. The impacts on the fish resources would generally be of the same nature but proportionally less than those from Plan 25N.

The effects on the marshes and nearshore zones of Lake Erie would be similar to those experienced in Lake St. Clair, however, the effects of lowering would be greater. Some shoals which would normally be submerged during times of higher water could be exposed, hence of little value to fish.

Weller and Spatcher (1965) and Weller and Fredrickson (1974) describe a marsh condition (hemi-marsh) which produces the greatest habitat diversity for wetland-dependent wildlife species, including favorable habitat for fish. High water levels, at least those held above the long-term mean, would tend to produce habitat conditions approaching the hemi-marsh. The regulation plans tend to limit the occurrence of highwater levels. Conversely, the more frequent incidence of low water levels due to the plans would encourage the development of denser stands of emergent vegetation at the expense of the open-water aquatic zone a situation less favorable to fish (See Section 4).

High waters would facilitate fish passage between the lake and the wetland and thus permit fish spawning (e.g., northern pike) as well as the wetland rearing of forage fish. Plan 25N, in particular, would extend the duration and frequency of low levels. This could adversely affect fish by making spawning areas inaccessible, changing the thermal nature of the shallow embayments, and/or changing the quality and quantity of macrophyte communities. Under the regulation plans the high levels on both lakes would be affected to a greater degree than the lows. While changes may seem small on Lake St. Clair, it is a shallow lake with many of the unpopulated areas around the perimeter existing as marshes and wetlands vital to the survival of many fish species.

Lowering the high water levels with no corresponding lowering of the low levels would reduce the range of fluctuation and could result in dense areas of emergent or sedge meadow type vegetation. Moreover, more stable water levels would result in a more homogeneous vegetative composition within the wetland thereby reducing fish species diversity in these areas. Peat deposits would build up and the depth of water in the emergent marshes would be too shallow or the vegetation would become too dense to support most fish.

Since a number of the wetlands in the western basin of Lake Erie are diked and regulated, the importance of the unregulated wetlands to the aquatic ecosystem, and to fish directly, is enhanced. Further lowering of the lake's water level could result in an increase in diking to maintain wetland water levels for wildlife management, thereby removing additional wetland areas from potential use by fish.

A reduction in the hypolimnion volume would be experienced in the central and eastern basins of Lake Erie as a result of the regulation plans. Since Lake St. Clair and the western basin of Lake Erie do not develop stable stratification, there would be no hypolimnia effects in these areas. A 1-foot reduction in the Lake Erie central basin hypolimnion thickness could represent as much as a 15 percent reduction in the hyolimnion volume. The corresponding reduction in the eastern basin would be as great as 4 percent. During the period of stratification, a 1-foot level reduction from BOC would occur approximately 20 percent of the time under Plan 25N. Thus, the cold water habitat would decrease to the detriment of cold water fish. Plans 6L and 15S would cause insignificant reduction in the hypolimnion volumes and the effect on the cold water fish would, therefore, also be minimal.

Lowering the mean water level may result in the need for both harbor and channel dredging. This dredging could have an adverse impact on fish resources, both at the dredging site and at the material disposal location.

Upper Niagara River

Coble (1967) reports that smallmouth bass will not spawn if suitable spawning areas are not available. Although it is unlikely that

the increased velocities caused by regulation would sweep the bottom clear of needed spawning material, it is possible that the increased velocity itself would inhibit spawning activity. Smallmouth bass prefer spawning areas that have stable currents.

Smallmouth bass spawning is directly related to water temperature (Scott and Crossman 1973). The effect operations would have on the temperature regime of the river, particularly during spawning, is therefore a concern. Decreases in water temperature during spawning cause desertion of nests by males and halts spawning activity in both males and females. Schonberger (1978) in a study carried out along the north Lake Erie shoreline found that changes in temperature of as little as 2.3°C (12.7°C to 15°C) lead to nest desertion. If the eggs were already in the nest when this desertion occurs, the nest would be open to predation. Sudden changes in temperature may also result in the females becoming egg-bound which in turn may cause death (McKay 1963).

Operation of regulatory works with their associated increased flows could significantly increase the suspension of solids. Turbidity has caused failure of bass nests (Latta 1963). In addition, turbid waters have been shown to reduce the growth rate in fish (Bennett 1962).

The Upper Niagara River muskellunge has become well adapted to the present conditions of the river environment, particularly to the current regime. Unlike most other muskellunge populations, the Upper Niagara population appears to spend its entire life cycle in a lotic reverine habitat. The adaptability of the muskellunge to the sudden increases in current, which would be produced under regulation, is unknown.

The major spawning grounds of the Upper Niagara River muskellunge are protected from the main river current by Strawberry Island, which lies almost directly north from Squaw Island scheme. Strawberry Island has already been greatly reduced in size by erosion (Harrison 1978). The increase in river flow could increase the erosion rate of the island which in turn may destroy the spawning shoals and/or render them unusable.

Under regulation, the water levels immediately downstream of the regulatory works would be increased. This may cause some flow reversal in the creeks and flooding of gently sloping shorelines. These newly flooded areas would provide ideal spawning areas for pike and carp. However, if the operational mode was to change during the spawning season, the reproductive success of these two species would be jeopardized by: temporarily disrupting and/or causing a complete cessation of spawning activity for the season, or the destruction of eggs on spawning beds. Increased flows and water level fluctuations could also destroy aquatic vegetation which provides a protective habitat for young-of-the-year fishes and food organisms for juveniles and adults.

No site specific information has been provided concerning fish resources of the Lower Niagara River. However, impacts are expected to be small. Changes in water flows should have little impact since they

will be masked by the flow fluctuations caused by power production.

Lake Ontario:

Plan 25N appears to have little impact on the fish stocks of Lake Ontario. Since the lake is already regulated, the anticipated changes from BOC in water levels due to regulation would be small.

The levels of Lake Ontario would generally be increased with the regulation because of increased flow into the lake. If this increase were to be sustained abnormally high, there might be some die-off of emergent vegetation which, if severe enough, could damage fish stocks.

Regulation could alter the seasonal distribution of water levels. Specifically, when Plan 25N is compared to the BOC, the annual spring rate of increase in Lake Ontario water levels seems to change, with the high period delayed. This type of delay might impact the fish in the nearshore by affecting such things as spawning access and food sources.

As far as the aquatic biological community is concerned, the slight increase in mean monthly stages on Lake Ontario are probably inconsequential. However, the shift in seasonal occurrences of mean high and low levels, which would occur due to the operational pattern of the regulatory works; could have an undesirable effect on aquatic biota. The delays in the annual cycles of high and low water levels resulting from the implementation of Plan 25N, could, for example, induce the overwintering stages (generally non-motile) of certain aquatic animals to become located at sites closer to shore than would otherwise be the case, with resulting increased hazards of desiccation or freezing when high levels decline rapidly late in the year. Increased mortality of early life stages of fish might also result through indirect mechanisms, as for example from interference in the protective behavior of nest-building species such as black bass, or through increased opportunities for predation by vertebrates or invertebrates on fish eggs or larvae.

It is almost impossible to evaluate the consequences to a given species or community of organisms, of changes in seasonal patterns of high and low water or of alteration in the rates of change between successive stages. Nearshore aquatic communities are already under stress from a variety of man-made environmental changes (pollution, siltation, heated effluents, etc.). Additional stress in the form of altered water level regimes may, therefore, upset what could be precarious balances in littoral ecosystems with consequent detriment to fish communities or to invertebrate forms on which they depend.

St. Lawrence River:

The impact of the Lake Erie regulation on the fish resources of the St. Lawrence River has received only cursory review. As long as the Lake Ontario outflows are regulated under present Orders of Approval, with no physical modification of the river, little new impact on fish resources would be expected.

Table F-51
1Niagara River Site Specific Effects

Plan/Stress	Structural	Construction-Related	Operational 1/
6L	Minimal - least of the 3 structures due to nature and location of structure	Minimal due to: - minimal dredging - minor cofferdam - location in Black Rock	Mode of operation required to accommodate boating may have major impacts on Niagara River fisheries; resultant pulsing effect could: - interrupt spawning - induce thermal changes which would affect spawning success among other impacts - increase erosion of shoals and spawning beds resuspended sludge deposits
15S	Minimal due mainly to location	Minor due to location of activities so long as there is proper disposal of excavated material	As Above
25N	Most detrimental due to location and size of structure	Major effects due to: - blasting which will likely result in fish kills and since the fishery in the river is localized the impact would be severe - cofferdaming, altering flow patterns as water is bypassed (could result in bank erosion)	More continuous discharge is less detrimental than pulsing discharge, but the release of water could increase erosion.

1/ It should be noted that the impact due to regulatory works operation may be insignificant when compared to natural surges in Lake Erie outflow as a result of wind setup.

5.5 Evaluation Of Niagara Regulatory and St. Lawrence Works

Based upon a review of the Niagara River fish resources and the criteria developed for selecting the least environmentally damaging regulatory structure, site-specific effects of varying severity were identified for each of the regulatory works. These site-specific effects are summarized in Table F-51.

Under Category 3, channel enlargement in the St. Lawrence was considered. It appears that the magnitude of the dredging will change the physical condition of the river and result in major destruction of aquatic habitat. As input to the Winter Navigation Demonstration Program which also discussed similar dredging requirements, several environmental agencies are on record as opposing any major dredging activities in the International Section of the St. Lawrence River because of the extent and permanence of the natural resource impact due to habitat destruction.

Niagara River:

The Niagara River structure for Plan 25N could have a major effect on the Niagara River fish stocks. The impacts of structures associated with Plans 6L and 15S would be minimal.

Because of their respective locations, the structural impacts of Plans 6L and 15S alternatives to the Niagara River fish population would be minimal. For Plan 6L the regulatory works are to be located in the Black Rock Lock, therefore, isolated from the aquatic environment. Similarly, the structures for Plan 15S are to be located within a man-made diversion channel and away from the main watercourse.

The Plan 25N structure would be located in the Niagara River just downstream from the Peace Bridge. It could have a major efffect on the Niagara River fisheries, both on fish stocks and access to them by sports fishermen. This area currently supports smallmouth bass, walleye, and yellow perch, which provide the basis for good drift fishing. In addition, a cold water fishery has recently been developed in this section of the river as a result of the Lake Erie salmonid stock program.

Site-specific impacts relating to construction under the Plan 6L alternative would be minimal. This is due to the location of the construction activities in the Black Rock Lock and Canal, the minimal dredging required, and the lack of cofferdaming. The construction-related impacts of Plan 15S alternative also would be minor due to the location of the proposed structures. It is expected that upland disposal sites would be utilized for the excavated material from the construction of the diversion channel.

The construction-related activities of the Niagara River structure are expected to have adverse effects on fisheries and fish habitat. This is due to the required blasting, substrate removal, and cofferdaming within the Niagara River. Since in the vicinity of the regulatory works for Plan 25N the fish populations in the river are restricted to a relatively shallow and narrow area, the bedrock blasting

would result in major fish kills. This would be most devastating to the fish stocks, particularly if the blasting were to occur during spawning and egg incubation periods. Furthermore, the dredging required for the Plan 25N would remove the desirable shallow riffle with isolated deep pools habitats. This would affect the salmonid fishery (brown trout, rainbow trout, and coho) which, as mentioned previously, has developed in the area as a result of the salmonid stocking program. It is anticipated that the cofferdaming could interfere with boat access for fishing and could have serious detrimental effects on the bait fishery along the Canadian shore.

Operation of any of the regulatory works could adversely affect fish and fish habitat. In the case of Plans 6L and 15S Black Rock Canal alternatives, the mode of operation would produce a pulsing effect that could interrupt spring spawning activity, induce thermal changes adversely affecting spawning success, increase erosion of shoals and spawning beds and resuspend sludge deposits containing substances hazardous to fish. The more continuous discharge of a Niagara River structure would be less detrimental, but the release of water could create downstream erosional effects more severe than for the other structures.

From the review of the existing information on the upper Niagara River fisheries, it is indicated that the fish population of the river are very well adapted to the present river environment. The operation of any one of the regulatory works would introduce different hydrological and environmental conditions to the river. The adaptability of the fish populations to these changes is not known. However, significant deviations from the norm might have deleterious effects. The effects of the sporadic flow increases due to the operation of the regulatory works, however, may be insignificant when compared to the natural phenomena.

It is likely that some spawning occurs in the mouths of tributary creeks where the water temperature is markedly higher than that of the main river at the time of spawning (May-June). Surges of increased flow resulting from operation of regulatory works might cause temporary current reversals in the mouths of creeks and thus subject spawning fish to significant temperature fluctuations.

Major environmental concerns with respect to fish include:

1. The increased velocities in Black Rock Canal could resuspend sludge deposits which most likely contain organic wastes, inorganic silts, toxic metals, and chemicals that are known to be hazardous to fish. This concern relates only to Plans 6L and 15S.
2. There is a possibility that the increased discharges will cause thermal changes within the river. This could disrupt spawning activity and/or cause distribution changes in the fish stocks.

3. Increased erosion of Strawberry Island is possible. This could destroy the main spawning/nursery area of the muskellunge and smallmouth bass; the two most valued sport fish in the river.

St. Lawrence River:

An increased frequency of occurrences of high outflow should be seen in the St. Lawrence River for Category 2. This would probably have a minimum impact on fish. For Category 3 there would be a great deal of dredging in the river. This dredging would directly destroy habitat. There would also be an increase in turbidity and sediment load during dredging operations which would have an impact on the fish of the river.

5.6 Concluding Remarks And Recommendations

Focus has been placed on what impacts regulation would have on fish habitat and thus the fish resource. It is evident that certain nearshore areas of the Great Lakes provide essential spawning, nursery, and feeding areas for fish stocks. However, without the benefit of site-specific studies to determine how the regulation-induced changes in water levels would impact the fish utilizing these productive nearshore zones, definitive evaluation was not possible. If the habitat of a fish species is modified severely or destroyed through lake level changes, then the fish species has the potential of being affected to a similar degree. The impact would be felt throughout the system.

It does appear that the construction and operation of the regulatory works could cause adverse environmental effects of fish stocks and fishing activities in the Upper Niagara River. However, more detailed information is required on the biology and population dynamics of the Upper Niagara River fish populations before the regulatory works or plans can be adequately evaluated. At the very least, detailed environmental mapping and resource inventories would need to be carried out. It does appear, however, that the construction and operation of the regulatory works would cause serious adverse environmental effects in the Upper Niagara River.

Within the scope envisioned in the study plan, it was not possible to demonstrate a quantifiable relationship between the alteration of lake levels and the viability or productivity of the fish stocks. It must be assumed, however, that all the regulatory plans would have the potential to adversely affect the fisheries. The effects may be very significant depending on the magnitude of the lake level changes.

In the case of the Plan 25N, resulting changes predicted for the nearshore zone (See Section 4) have the potential to adversely affect the fish populations utilizing this very productive area.

Based on the preceding evaluation, the effects on the fisheries of lowering water levels from the BOC in the case of the Plans 6L and 15S would be undetectable on the basis of currently available data and knowledge.

In the long term, the lowering of Lakes Erie and St. Clair water levels by the Plan 25N appear to have the potential to cause a permanent displacement, impairment or loss of "essential living areas" such as spawning grounds, nursery areas, and/or feeding areas within the nearshore zone. These areas, depending on their physical features (e.g., depth contour, shoals, embayments etc.) could reestablish themselves lakeward, however, the extent of this potential is not known and may not take place at all.

The Plan 25N also would have an effect on the extreme lows. This could adversely affect the fisheries by making spawning areas inaccessible, changing the thermal nature of the shallow embayments and/or changing the quality and quantity of macrophyte associations.

There are very little biological data available to evaluate the impacts of regulation on the Upper Niagara bait fishery. More information would be required on the biology and population dynamics of the bait species, particularly the emerald and spottail shiners. At the very least, information on the temperature and dates of first spawning, the duration of spawning, and the spawning areas would need to be resolved. Movement patterns of the populations and habitats of early young-of-the-year would need to be determined.

It should be remembered also that bait fish form the forage base for many piscivorous fish of the Niagara River. Any impact regulation would have on these bait fish species would produce an impact farther up the food chain.

Fisheries research on the Niagara River has concentrated on only two species (smallmouth bass and muskellunge). More data are required on other species (for example, the bait fish and salmonids) which also provide considerable economic and recreational value to the area. Most research has centered around the adult life stage. The location of rearing grounds and the habitat preferences of the early season young-of-the-year have not been determined.

Under Category 3, the levels of Lake Ontario would be changed somewhat as compared to the BOC. The fluctuation range would be decreased. This could lead to problems similar to those which might occur in Lake Erie and Lake St. Clair. Lake Ontario level fluctuations would be greatly reduced resulting in wetlands becoming mesophytic and perhaps choked with cattail.

The St. Lawrence River would see the greatest impact as a result of Category 3 operations through the large amount of dredging required. The dredging would initially destroy benthic organisms which are a food source for many fish species. These organisms may reinvade the bottom over time, however, maintenance dredging could be necessary and thus repeated destruction of benthos would be expected. Changes in currents, sediment load and turbidity would also occur thus impacting the fish populations of the river.

Section 6

SUMMARY

Section 3, 4 and 5 present the evaluation of the regulation plans and associated structural works on water quality, wildlife/wetlands and fish. The effort was generally based upon existing information and encompassed both quatitative to qualitative analyses. The following capsulizes and attempts to put into perspective the findings of these analyses.

6.1 Water Quality

Lakes Erie and Ontario water quality generally would not be significantly altered by any of the regulation plans. The biggest impacts both adverse and beneficial, would result from Plan 25N. Plans 15S and 6L would have impacts similar to 25N but of a lesser magnitude.

It appears that, of the Niagara regulatory works studied, the river structure would prove least harmful to the water quality.

The most significant impact of lowering the levels on Lakes Erie and St. Clair would be a reduction in volume in shallow embayments with a small lake-bay interface. The resultant dilution capacity loss would enhance the potential for increased embayment pollutant concentration. This condition could be critical in the event of a "slug" pollutant load (e.g., accidental spill, bypass due to equipment malfunction, etc.). On the other hand, lowered lake levels would enhance the effects of water exchange between lake and bay, a process which usually aids to dilute contaminants. However, the latter process is periodic and not approximately significant to adequately neutralize the adverse effects on water quality of embayment volume (dilution capacity) loss.

Under Plan 25N, Lake Erie shore erosion damages would decrease as much as 18 percent. Assuming that the reduction in shoreline erosion is directly proportional to the damage reduction, Lake Erie biologically available phosphorus inputs from shore erosion could decrease by as much as one percent. Although the greatest retardation in eutrophication of Lake Erie would result from the control of anthropogenic sources of phosphorus, it is reasonable to assume that any reduction in natural phosphorus inputs would have a positive effect in achieving that goal.

Under Plan 25N the Lake Erie central basin hypolimnion volume loss could amount to as much as 15 percent during certain years resulting in a comparable loss of total hypolimnion oxygen reserves. However, no statistically significant change in the hypolimnion oxygen concentrations would occur, nor would hypolimnetic anoxia occur significantly sooner under regulation. The Lake Ontario hypolimnion would not be appreciably affected by any of the regulation plans.

All regulation plans would reduce nearshore turbidity on Lake Erie provided that erosion would be reduced with regulation. The projected mean turbidity decreases would be relatively small even under Plan 25N.

Plan 25N would increase the long-term annual mean Cladophora production in Lake Erie by approximately two percent. In certain years, however, maximum annual increases of up to 14 percent could be expected in some aeas. No appreciable effect on Cladophora production in Lake Ontario is expected under any of the plans.

Limited regulation of Lake Erie would not significantly affect the quantity of water available for dilution of wastses emanating from nearshore outfalls. However, some aesthetic drawbacks in the nearshore area may be noticed due to the possible exposure of outfall heads.

6.2 Wildlife/Wetlands

The lowering of the long-term water levels of Lakes Erie and St. Clair could create large areas of sedge marsh and meadow environments, which would decrease the diversity and density of wetland-dependent wildlife species while enhancing habitat conditions for species not necessarily dependent on wetlands. The landward edges of wetlands exposed and no longer periodically flooded would tend to progress to shrubs and trees if left undisturbed by human activity. A more probable result would be the encroachment of development into the resultant dry zone along the perimeter of the wetlands. This might generate additional pressure for converting wetlands to alternate uses.

Plan 25N would be the most damaging plan, resulting in permanent loss of some wetland area especially around the landward edges of existing wetlands. A shift in vegetation zones would be expected with sedge/meadow zones becoming more prevalent while open-water/submergent zones are reduced in area. Due to the increased stability of water levels (reduced fluctuation range), long-term changes would result, through succession, in less diversity of vegetation and more areas of emergents and sedges. Shifts to sedge/meadow/emergent-dominated wetlands would decrease the diversity and density of wetland-dependent wildlife (e.g., waterfowl, muskrats), while providing habitat for terrestrial wildlife species.

Plan 15S would also be damaging to the vegetative structure producing increases in sedge/meadow zones at the expense of open-water/submergent zones, and would csause wildlife species shifts. The area loss around the landward edges could still be extensive; however, not as ggreat as Plan 25N. It is felt that under Plan 15S, at least for Lake St. Clair, there would be sufficient variability in lake levels to promote species diversity. In Lake Erie, however, there may not be ample variation.

Plan 6L is the least detrimental. However, vegetative zone shifts of lesser magnitudes from open-water aquatics to emergents and sedge/meadow would still occur.

All three regulation plans under Category 2 would produce similar changes in the Lake Ontario water level regime. The impacts of a reduced predominance of sedge/meadow and emergent zones during low and mean water periods and an increased die-back of emergents during

increased high water periods are, overall, regarded as indeterminable to sightly beneficial to wetlands and wetland-dependent wildlife.

It is not expected that any of the Niagara River regulatory alternatives would greatly affect wildlife.

6.3 Fish

Focus has been placed on what impacts regulation would have on fish habitat and thus the fish resource. It is evident that certain nearshore areas of the Great Lakes provide essential spawning, nursery, and feeding areas for fish stocks. However, without the benefit of site-specific studies to determine how the regulation-induced changes in water levels would impact the fish utilizing these productive nearshore zones, definitive evaluation is not possible. If the habitat of a fish species is modified severely or destroyed through lake level changes, then the fish species has the potential of being affected to a similar degree. The impact would be felt throughout the system.

It does appear that the construction and operation of the regulatory works could cause adverse environmental effects of fish stocks and fishing activities in the Upper Niagara River. However, more detailed information is required on the biology and population dynamics of the Upper Niagara River fish population before the regulatory works can be adequately evaluated.

ANNEX 1

Program SIMU

Simulates nearshore turbidity for BOC and Plan

```
      PROGRAM SIMU (INPUT,OUTPUT,TAPE60=INPUT,TAPE61=OUTPUT)
C*********************************************************************
C                                                                    *
C  PROGRAM TO SIMULATE NEARSHORE TURBIDIY WITH VARIATIONS IN         *
C  TOE-OF-BLUFF WAVE ENERGY.                                         *
C                                                                    *
C*********************************************************************
      DIMENSION WLBOC(10,12), WLPLAN(10,12), TURB(10,12), TURBNEW(10,12)
     1, TUROBS(10,12), DIFF(10,12), DIFFPER(10,12)
     2, TIME(10,12), OBSDIFF(10,12), PER(10,12), TITLE(20)
     3, ELEV(90), TBWAEN(90,12), TBBOC(10,12), TBPLAN(10,12)
C READ THE PLAN BEING COMPARED.
      READ (60,500) (TITLE(I),I=1,20)
 500  FORMAT (20A4)
C READ THE WATERLEVELS FOR THE BASIS OF COMPARISON AND THE PLAN BEING EXAMINED.
C PERIOD OF COMPARISON IS 1967 TO 1976.
      READ (60,100) ((WLPLAN(I,J),J=1,12),I=1,10)
      READ (60,100) ((WLBOC(I,J),J=1,12),I=1,10)
 100  FORMAT (12F6.2)
      DO 99 I=1,10
      DO 99 J=1,12
 99   READ (60,101) TIME(I,J), TUROBS(I,J)
 101  FORMAT (A5,9X,F6.2)
      DO 103 I=1,90
      READ (60,102) ELEV(I), (TBWAEN(I,J),J=1,12)
 103  CONTINUE
 102  FORMAT (F4.1,4X,12F6.0)
      WRITE (61,298)
 298  FORMAT (1H1)
      WRITE (61,299) (TITLE(I),I=1,5)
 299  FORMAT (T40,'############################################',
     1/,T40,'#  EVALUATION FOR ',5A4,'  #',/,T40,
     2'############################################',/)
      WRITE (61,300)
 300  FORMAT (4X,'TIME',4X,'WATER  LEVELS',3X,
     1'CALCULATED WAVE ENERGY',2X,
     2'PREDICTED TURBIDITY',4X,'DIFF',5X,'% DIFF',5X,'OBS',5X,
     2'OBSDIFF',4X,'%DIFF'
     3,/,12X,'BOC',6X,'TCFS',8X,'BOC',5X,'TCFS',11X,
     4'BOC',6X,'TCFS',/,
     5'    -----  --------------       -------------_',9X,
     6'______________      ----------------     -----------------------
     7_')
      TOTAL = 0.0
      ADD1 = 0.0
      ADD2 = 0.0
      ADD3 = 0.0
      TOTAL1 = 0.0
      TOTAL2 = 0.0
      TOTAL3 = 0.0
      DO 98 I=1,10
      DO 98 J=1,12
      IF(I.EQ.6.AND.J.EQ.1)  GO TO 12
      GO TO 8
 12   WRITE (61,298)
      WRITE (61,299) (TITLE(L),L=1,5)
      WRITE (61,300)
 8    WL = WLBOC(I,J)
      CALL WATER (I,J,TBWAEN,WL,TB)
      TBBOC(I,J) = TB
      GO TO(5,5,1,1,1,1,1,1,1,1,1,5),J
 1    TURB(I,J) = 13.03+0.0006129*TBBOC(I,J)
 6    WL = WLPLAN(I,J)
      CALL WATER (I,J,TBWAEN,WL,TB)
      TBPLAN(I,J) = TB
      GO TO (5,5,10,10,10,10,10,10,10,10,10,5),J
 10   TURBNEW(I,J) = 13.03+0.0006129*TBPLAN(I,J)
      GO TO 600
C SETTING OF JANUARY,FEBRUARY AND DECEMBER TO PRINT
C AN ASKERIK.
 5    TURB(I,J) = 1000000.0
      TURBNEW(I,J) = 1000000.0
      DIFF(I,J) = 1000000.0
      DIFFPER(I,J) = 1000000.0
      TBPLAN(I,J) = 1000000.0
      TUROBS(I,J) = 1000000.0
      OBSDIFF(I,J) = 1000000.0
```

```
      PER(I,J) = 1000000.0
      GO TO 70
600   IF(TURBNEW(I,J).LT.0.0) TURBNEW(I,J) = 0.0
      DIFF(I,J) = TURBNEW(I,J)-TURB(I,J)
      DIFFPER(I,J) = (DIFF(I,J)/TURB(I,J))*100.0
      OBSDIFF(I,J) = TURB(I,J)-TUROBS(I,J)
      IF(TUROBS(I,J).EQ.0.0)  GO TO 1000
      PER(I,J) = (OBSDIFF(I,J)/TURB(I,J))*100.0
      TOTAL1 = TOTAL1 + PER(I,J)
      TOTAL3 = TOTAL3 + OBSDIFF(I,J)
      ADD1 = ADD1 + TURB(I,J)
      ADD2 = ADD2 + TURBNEW(I,J)
      ADD3 = ADD3 + TUROBS(I,J)
1000  IF(TUROBS(I,J).EQ.0.0) TUROBS(I,J)=1000000.0
      IF(TUROBS(I,J).EQ.1000000.0)  PER(I,J)=1000000.0
      IF(TUROBS(I,J).EQ.1000000.0)  OBSDIFF(I,J)=1000000.0
      TOTAL = TOTAL+DIFFPER(I,J)
      TOTAL2 = TOTAL2 + DIFF(I,J)
70    IF(J.GT.1)  GO TO 7
      WRITE (61,303)
303   FORMAT (1H0)
7     WRITE (61,302)  TIME(I,J), WLBOC(I,J), WLPLAN(I,J),
     1 TBBOC(I,J), TBPLAN(I,J), TURB(I,J),
     2 TURBNEW(I,J), DIFF(I,J), DIFFPER(I,J), TUROBS(I,J)
     3,OBSDIFF(I,J), PER(I,J)
302   FORMAT (4X,A5,2X,F6.2,3X,F6.2,5X,F7.0,1X,F7.0,9X,
     1 F5.1,4X,F5.1,5X,F6.1,4X,F6.1,5X,F4.0,5X,F6.1,5X,F6.1)
98    CONTINUE
      PDM = TOTAL/90.0
      PDM1 = TOTAL1/47.0
      DF = TOTAL2/90.0
      ODF = TOTAL3/47.0
      XMEAN1 = ADD1/90.0
      XMEAN2 = ADD2/90.0
      XMEAN3 = ADD3/47.0
      WRITE(61,306) XMEAN1, XMEAN2, XMEAN3
306   FORMAT (T56,'*****',4X,'*****',T96,'****',
     1 /,T5,'MEANS',T56,F5.1,4X,F5.1,T96,F4.1)
      WRITE (61,304) DF, PDM, ODF, PDM1
304   FORMAT (T75,'______',T85,'______',T105,'______',5X,'______',/,
     1T5,' PERCENTAGE DIFFERENCE',T75,F6.1,T85,F6.1,T105,F6.1,5X,F6.1)
      SUM1 = 0.0
      SUM2 = 0.0
      SUM3 = 0.0
      SUM4 = 0.0
      DO 60 I=1,10
      DO 61 J=1,12
      GO TO(61,61,62,62,62,62,62,62,61,61,62,61),J
62    SUM1 = SUM1+(DIFF(I,J)-DF)**2
      SUM2 = SUM2+(DIFFPER(I,J)-PDM)**2
      IF(I.LE.3) GO TO 61
      SUM3 = SUM3+(OBSDIFF(I,J)-ODF)**2
      SUM4 = SUM4+(PER(I,J)-PDM1)**2
61    CONTINUE
60    CONTINUE
      SD1 = SQRT(SUM1/89.0)
      SD2 = SQRT(SUM2/89.0)
      SD3 = SQRT(SUM3/46.0)
      SD4 = SQRT(SUM4/46.0)
      WRITE (61,305) SD1, SD2, SD3, SD4
305   FORMAT (T6,'STANDARD DEVIATIONS',
     1T75,F6.2,T85,F6.2,T105,F6.2,5X,F6.2)
      STOP
      END
```

EXAMPLE Input Data, Elgin Area Water System, Lake Erie.

First set of ten years, Plan 25N Lake Erie Levels.

Second set of ten years, BOC Lake Erie Levels.

```
PLAN 77 CAT 1 25,000 CFS.
569.49569.61569.72570.31570.59570.54570.51570.17569.72569.48569.37569.53     1967
569.64569.95569.89570.20570.20570.40570.46570.29569.98569.58569.38569.57     1968
569.67570.04569.91570.49571.01571.31571.49571.25570.68570.20569.88569.91     1969
569.43569.41569.74570.38570.80571.03571.16571.04570.83570.65570.40570.35     1970
570.17570.05570.53570.67570.71570.83570.65570.47570.45570.53570.13570.07     1971
570.15570.03570.40570.85571.27571.34571.42571.22571.05570.92571.04571.29     1972
571.40571.38571.68572.22572.26572.53572.42572.12571.66571.30571.00571.04     1973
571.18571.54572.02572.33572.40572.42572.20571.82571.38570.96570.85571.02     1974
571.17571.31571.71571.76571.81571.91571.74571.54571.68571.40571.15571.17     1975
571.03571.14572.36572.45572.43572.23572.14571.84571.34571.05570.68570.45     1976

569.92569.96570.02570.57570.93570.92570.94570.75570.42570.27570.24570.4[illegible]     1967
570.61570.96570.92571.25571.26571.47571.53571.37571.06570.68570.49570.69     1968
570.80571.17571.04571.61572.12572.40572.59572.35571.81571.36571.07571.13     1969
570.68570.58570.76571.26571.5[illegible]571.71571.76571.59571.33571.22571.13571.19     1970
571.10571.05571.57571.74571.81571.95571.79571.62571.62571.71571.32571.27     1971
571.36571.24571.60572.05572.45572.51572.59572.40572.24572.12572.24572.56     1972
572.61572.60572.90573.44573.47573.74573.63573.34572.87572.52572.25572.30     1973
572.46572.82573.30573.60573.67573.67573.43573.04572.59572.17572.08572.26     1974
572.41572.55572.94572.99573.03573.12572.94572.73572.75572.39572.09572.08     1975
572.01572.06573.13573.21573.28573.14573.10572.84572.36571.99571.47571.12     1976
```

Month of record	offshore wave energy (recorded)
67JAN	158540
67FEB	124170
67MAR	60692
67APR	73987
67MAY	50163
67JUN	43416
67JLY	35202
67AUG	35245
67SEP	41205
67OCT	126771
67NOV	126771
67DEC	114220
68JAN	93949
68FEB	144377
68MAR	99722
68APR	134769
68MAY	74750
68JUN	61224
68JLY	51082
68AUG	29586
68SEP	35985
68OCT	85651
68NOV	107223
68DEC	168150
69JAN	174741
69FEB	16282
69MAR	99175
69APR	84330
69MAY	35225
69JUN	79282
69JLY	27356
69AUG	29033
69SEP	36310
69OCT	91497
69NOV	103614
69DEC	51669

Month of record	Recorded water level	Toe-of-bluff wave energy (recorded)	offshore wave energy (recorded)	recorded turbidity	recorded temperature	Alum dosage	Chloride dosage
70JAN	57058	94799	153032	6	22		
70FEB	57046	86921	119600	7	22		
70MAR	57055	42653	67617	29	22		
70APR	57107	66966	94533	64	59		
70MAY	57134	66660	105478	21	122		
70JUN	57146	32768	62341	17	161		
70JLY	57162	20009	48615	16	183		
70AUG	57144	6682	28607	10	222		
70SEP	57118	18541	50113	17	216		
70OCT	57104	32745	68500	48	172		
70NOV	57101	291886	230332	83	116		
70DEC	57099	134290	166821	101	61		
71JAN	57089	114771	166053	34	16		
71FEB	57081	214036	250917	2	16		
71MAR	57129	100947	121829	48	16		
71APR	57152	57665	62867	29	55		
71MAY	57167	70702	74457	15	100		
71JUN	57178	7337	26519	15	138		
71JLY	57166	23891	40597	21	194		
71AUG	57149	10691	30522	12	177		
71SEP	57157	7444	23569	20	20		
71OCT	57122	14276	40434	30	177		
71NOV	57080	56250	115076	42	116	20193	2411
71DEC	57084	153640	157273	55	10	20887	1645
72JAN	57096	188596	191953	43	61	16469	1611
72FEB	57087	87142	113435	4	44	7017	1604
72MAR	57128	118180	123289	19	55	14600	1765
72APR	57170	41218	54267	37	66	17055	1590
72MAY	57216	68972	67699	15	133	13409	1880
72JUN	57223	26752	45885	9	127	12886	2356
72JLY	57246	32152	42647	13	155	12022	1989
72AUG	57227	21738	43335	14	166	15799	2543
72SEP	57216	27262	46952	21	183	13995	2441
72OCT	57195	43907	52269	52	161	22987	2558
72NOV	57209	60488	79718	48	116	20872	2175
72DEC	57235	142886	120930	83	77	23686	1865
73JAN	57244	264477	213490	36	50	16393	1872
73FEB	57239	52840	63386	15	50	12354	1812
73MAR	57273	113807	83852	55	66	21649	2295
73ARP	57320	135234	97514	56	94	21614	2165
73MAY	57320	165427	96863	26	133	16792	2282
73JUN	57346	76523	68970	23	144	16561	2635
73JLY	57320	46061	54500	29			
73AUG	57292	15338	31010	7	188	12199	3445
73SEP	57233	18291	31025	13	183	14079	3586
73OCT	57210	25067	40096	30	166	18669	2960
73NOV	57181	83090	102024	42	122	18519	2391
73DEC	57182	178761	177869	69	61	20919	1960

74JAN	57202	157793	131720	29	33	18500	2096
74FEB	57231	169331	102820	22	33	13713	1910
74MAR	57280	136659	85289	52	38	22407	2204
74APR	57316	244609	135172	61	66	23121	2055
74MAY	57322	125288	81784	25	100	515	2240
74JUN	57320	140861	87386	16	133	13583	2665
74JLY	57300	39741	47950	19	161	15704	2950
74AUG	57269	43520	49301	15	194	17621	3630
74SEP	57228	42089	60089	21	177	17572	3275
74OCT	57179	62181	74534	26	144	16829	2888
74NOV	57172	66927	100493	45	111	16557	2345
74DEC	57184	39321	67715	56	61	19129	1875
75JAN	57201	211827	154335	64	33	20490	1636
75FEB	57210	51677	73465	28	33	14459	1694
75MAR	57244	57493	56465	59	33	23466	1962
75APR	57251	93950	61525	38	40	24164	1989
75MAY	57258	23417	34452	9	90	9916	2265
75JUN	57273	92576	71952	19	120	14335	2625
75JLY	57257	18377	31435	16	160	16862	2977
75AUG	57236	9589	33229	9	180	31545	3240
75SEP	57243	25341	37670	42	190	23429	3057
75OCT	57201	5798	75781	33	140	22388	2890
75NOV	57189	181744	147932	66	110	25529	2714
75DEC	57173	82113	92813	66	50	23005	2185
76JAN	57178	142362	137048	27	20	14405	1989
76FEB	57182	201214	202735	18	20	11206	1850
76MAR	57277	302731	176640	107	30	30287	2180
76APR	57280	20376	33518	30	70	17400	2090
76MAY	57287	98484	83659	28	110	18462	2420
76JUN	57280	59725	62373	22	150	17631	3196
76JLY	57277	19338	34749	18	150	10927	2975
76AUG	57257	6663	24310	10	180	9264	3645
76SEP	57215	10558	29652	19	180	11583	1753
76OCT	57175	42056	56054	36	140	13695	2595
76NOV	57126	48228	95436	36	70	14195	2215
76DEC	57080	63990	108716	8	30	438	2005

toe-of-bluff wave energy at various lake levels for 1967-1976 period.

57001967	9674	7508	2357	2518	2239	665	699	556	1308	4380	4538	5168
57001968	3326	8688	4195	9096	2991	2111	851	149	743	3467	4035	11322
57001969	10006	311	5583	4146	841	2865	564	448	312	3359	3698	1530
57001970	7737	7533	3456	4670	4065	1788	955	335	1079	2083	2134	9689
57001971	8491	16436	6594	3494	3878	273	1197	538	340	820	4030	11945
57001972	13897	6469	8051	2112	3072	981	1093	656	1098	1942	2572	6154
57001973	11454	2018	4247	4121	5230	1597	1075	306	651	980	4184	9534
57001974	8051	8248	5796	8809	4144	4104	1024	1343	1588	3041	3311	1714
57001975	11411	2125	2230	4205	649	3302	540	236	832	2370	10215	4542
57001976	7709	10667	12714	556	3753	1996	504	155	366	2020	2996	4600
57051967	11377	8894	2866	3098	2692	853	872	705	1593	5519	5522	6186
57051968	4040	10164	5061	10730	3633	2574	1089	203	948	4197	4864	13237
57051969	11851	395	6571	4992	1040	3495	708	559	413	4114	4504	1882
57051970	9182	8871	4036	5528	4898	2193	1199	429	1358	2580	25454	11434
57051971	10087	19193	7814	4148	4623	360	1470	675	440	1031	4902	13833
57051972	16334	7643	9472	2554	3709	1224	1355	856	1379	2388	3148	7328
57051973	13576	2462	5083	4926	6232	2001	1344	399	808	1221	5047	11325
57051974	9448	9553	6759	10346	4891	4949	1272	1655	1968	3668	4054	2139
57051975	13297	2604	2700	4916	827	3978	687	3315	1043	2933	11903	5372
57051976	9173	12595	14788	696	4416	2420	639	208	464	2476	3672	5569
57101967	13398	10549	3492	3816	3239	1096	1090	897	1944	6469	6729	7419
57101968	4916	11910	6113	12668	4417	3145	1398	272	1212	5090	5873	15496
57101969	14052	503	7743	6019	1290	4272	890	700	548	5045	5492	2319
57101970	10910	10458	4726	6553	5913	2695	1509	551	1712	3203	29296	13512
57101971	12000	22441	9268	4929	5517	476	1810	850	569	1301	5970	16043
57101972	19220	9040	11145	3093	4485	1532	1683	1119	1737	2941	3056	8735
57101973	16108	3008	6097	5905	7437	2512	1683	522	1006	1524	6098	13466
57101974	11103	11083	7898	12166	5786	5977	1582	2044	2443	4432	4973	2673
57101975	15518	3198	3274	5757	1056	4800	874	421	1311	3634	13894	6364
57101976	10928	14890	17223	874	5210	2937	812	279	590	3038	4508	6754
57151967	15800	12526	4263	4708	3901	1411	1366	1144	2377	7883	8212	8917
57151968	5992	13978	7395	14971	5378	3851	1797	378	1552	6185	7101	18166
57151969	16682	640	9137	7268	1605	5230	1121	881	728	6195	6708	2864
57151970	12980	12341	5546	7780	7152	3317	1906	710	2161	3986	3748	15988
57151971	14295	26271	11004	5863	6593	630	2275	1073	739	1647	7281	18636
57151972	22642	10709	13134	3752	5434	1921	2096	1465	2192	3631	4730	10426
57151973	19135	3679	7327	7099	8888	3159	2112	684	1255	1907	7383	16026
57151974	13067	12878	9250	14324	6863	7232	1971	2532	3039	5365	6110	3348
57151975	18138	3935	3975	6751	1351	5801	1115	564	1652	4511	16246	7552
57151976	13033	17625	20087	1100	6163	3570	1036	376	752	3734	5542	8202
57201967	18661	14893	5214	5817	4704	1819	1715	1463	2910	9624	10040	10742
57201968	7319	16435	8958	1710	6558	4725	2314	520	1994	7529	8602	21329
57201969	19830	817	10299	8790	2002	6416	1417	1114	971	7620	820	3543
57201970	15465	14581	6528	9253	8668	4091	2413	917	2739	4974	38914	18945
57201971	17053	30799	13081	6984	7893	837	2769	1360	982	2092	8893	21688
57201972	26709	12704	15503	4559	6597	2415	2417	1923	2773	4492	5808	12485
57201973	22758	4505	8824	8559	10640	3984	2654	898	1569	2395	8956	19091
57201974	15404	14989	10859	16887	8160	6767	2460	3146	3790	6509	7521	4201
57201975	21237	4853	4834	7929	1732	7024	1424	757	2090	5608	19034	8981
57201976	15562	20891	23461	1388	7312	4347	1324	507	963	4598	6826	9980
57251967	22076	17732	6393	7198	5680	2351	5158	1860	3570	11775	12299	12972
57251968	8959	19361	10871	20974	8009	5812	2988	717	2509	9185	10441	25085
57251969	23604	1045	12785	10649	2506	7888	1795	1417	1300	9387	10055	4394
57251970	18455	17251	7707	11026	10529	5056	3067	1189	3477	6223	44918	22483
57251971	20376	36162	15568	8331	9465	1114	3444	1730	1257	2668	10882	25282
57251972	31549	15096	18330	5550	8023	3045	3278	2528	3516	5571	7143	14920
57251973	27103	5526	10652	10353	12761	5037	3343	1183	1969	3016	10887	22782
57251974	18193	17477	12780	19938	9731	10648	3077	3920	4738	7914	9276	5284
57251975	24910	5998	5889	9330	2227	8521	1822	1019	2654	6986	22347	10702
57251976	18607	24799	27444	1756	8703	5303	1700	687	1237	5673	8421	12165
57301967	26161	21143	7858	8923	6869	3044	2723	2424	4390	14442	15096	15709
57301968	10995	22657	13216	24869	9799	7168	3867	993	3320	11231	12699	29559
57301969	28140	1341	15165	12926	3149	9719	2284	1014	1746	11505	12346	5465
57301970	22061	20439	9128	13166	12821	6263	3914	1548	4429	7810	51907	26726
57301971	24386	42526	18555	9953	11371	1488	4301	2212	1647	3416	13341	29534
57301972	37323	17973	21714	6772	9780	3852	4119	3332	4470	6927	8799	17894
57301973	32321	6790	12888	12564	15333	6386	4220	1563	2478	3813	13265	27213
57301974	21528	20416	15082	23579	11638	12961	3856	4903	5938	9648	11464	6663
57301975	29275	7432	7189	10998	2869	10360	2337	1378	3382	8719	26300	12785
57301976	22279	29484	32157	2230	10396	6483	2190	933	1598	7013	10410	14860
57351967	31060	25251	9684	11082	8323	3952	3448	3140	5411	17757	18572	19078
57351968	13530	27046	16098	29527	12013	8864	5018	1383	4303	13767	15482	34904
57351969	33604	1742	18025	15720	3973	12006	2917	2338	2354	14325	15193	6814
57351970	26425	26255	10850	15759	15654	7780	5016	2024	5658	9831	60057	31825
57351971	29241	50096	22148	11912	13691	1995	5396	2840	2167	4396	16390	34577
57351972	44224	21443	25775	8284	11950	4888	5195	4404	5699	8640	10857	21503
57351973	38601	8360	15635	15302	18461	8123	5343	2071	3131	4839	16203	32550
57351974	25531	23897	17850	27935	13965	15813	4846	6156	7464	11798	14199	8422
57351975	34476	9232	8795	12991	3709	12627	3003	1870	4329	10907	31034	15315
57351976	26719	35112	37747	2842	12468	7945	2834	1273	2073	8689	12894	18195
57401967	36953	30213	11971	13792	10106	5146	4384	4087	6688	21697	22906	23248
57401968	16703	32085	19654	35110	14758	10998	6531	1935	5598	16922	18923	41314
57401969	40204	2225	21475	19163	5035	14871	3742	3037	3189	17752	18744	8532
57401970	31724	28837	12948	18914	19169	9694	6460	2459	7256	12418	69580	37970
57401971	35127	59124	26483	14284	16525	2685	6804	3668	2866	5686	20183	40583
57401972	52495	25645	30666	10162	14638	6228	6579	5836	7290	10812	13425	25897
57401973	46176	10316	19019	18706	22280	10369	6788	2754	3974	6168	19847	38994
57401974	30353	28030	21196	33159	16817	19341	6108	7762	9413	14474	17630	10678
57401975	40695	11503	10789	15377	4810	15431	3870	2549	5568	13678	36728	18403
57401976	32097	41891	44395	3638	15018	9765	3687	1744	2705	10793	16007	22336

AD-A114 590 INTERNATIONAL LAKE ERIE REGULATION STUDY BOARD F/G 6/6

LAKE ERIE WATER LEVEL STUDY. APPENDIX F. ENVIRONMENTAL EFFECTS.(U)

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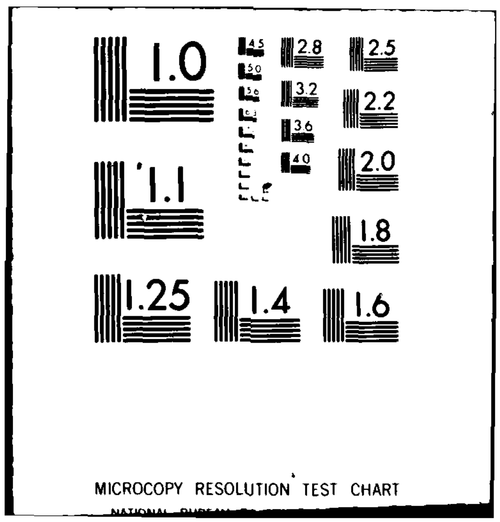
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MICROCOPY RESOLUTION TEST CHART

Example output Elgin Area Water System Plan 25N.

EVALUATION FOR PLAN 77 CAT 1 25,000

TIME	WATER LEVELS POC	WATER LEVELS TCFS	CALCULATED WAVE ENERGY POC	CALCULATED WAVE ENERGY TCFS	PREDICTED TURBIDITY POC	PREDICTED TURBIDITY TCFS	DIFF	% DIFF	OBS	OBSDIFF	%DIFF
67JAN	569.96	569.49	9674.	******	*****	*****	******	******	****	******	******
67FEB	569.99	569.61	7509.	******	*****	*****	******	******	****	******	******
67MAR	570.03	569.72	2341.	2357.	31.3	31.2	-.1	-.2	****	******	******
67APR	570.57	570.31	3133.	2979.	33.0	32.3	-.7	-2.0	****	******	******
67MAY	570.92	570.59	3151.	2733.	14.9	14.6	-.3	-2.0	****	******	******
67JUN	570.92	570.54	1057.	372.	13.2	13.0	-.2	-1.2	****	******	******
67JLY	570.93	570.51	1054.	976.	11.3	10.7	-.6	-5.0	****	******	******
67AUG	570.72	570.17	793.	597.	11.4	[illegible]	-.5	-5.4	****	******	******
67SEP	570.39	569.72	1525.	******	*****	*****	******	******	****	******	******
67OCT	570.22	569.48	4793.	******	*****	*****	******	******	****	******	******
67NOV	570.17	569.77	4473.	4533.	40.2	33.6	-.6	-1.5	****	******	******
67DEC	570.38	569.53	5347.	******	*****	*****	******	******	****	******	******
68JAN	570.57	569.64	4075.	******	*****	*****	******	******	****	******	******
68FEB	570.87	569.95	11455.	******	*****	*****	******	******	****	******	******
68MAR	570.92	569.99	5734.	4135.	38.2	35.0	-3.2	-8.3	****	******	******
68APR	571.15	570.20	13353.	9750.	53.8	46.4	-7.4	-13.8	****	******	******
68MAY	571.16	570.20	4725.	3249.	16.2	15.0	-1.2	-7.5	****	******	******
68JUN	571.37	570.40	3667.	2491.	15.3	14.4	-1.0	-6.4	****	******	******
68JLY	571.43	570.46	1741.	1070.	13.3	11.3	-2.1	-15.4	****	******	******
68AUG	571.28	570.29	334.	190.	[illegible]	9.6	-.5	-5.2	****	******	******
68SEP	570.97	569.58	1135.	******	*****	*****	******	******	****	******	******
68OCT	570.59	569.59	4359.	******	*****	*****	******	******	****	******	******
68NOV	570.60	569.39	4639.	4035.	39.9	38.7	-1.2	-3.0	****	******	******
68DEC	570.61	569.57	13734.	******	*****	*****	******	******	****	******	******
69JAN	570.72	569.67	12913.	******	*****	*****	******	******	****	******	******
69FEB	571.08	570.04	525.	******	*****	*****	******	******	****	******	******
69MAR	570.96	569.61	7525.	5593.	42.0	37.8	-4.2	-10.0	****	******	******
69APR	571.53	570.64	7361.	6475.	41.5	36.6	-4.9	-11.8	****	******	******
69MAY	572.04	571.01	2042.	1216.	14.0	13.4	-.6	-4.4	****	******	******
69JUN	572.32	571.31	7338.	4866.	18.4	16.3	-2.1	-11.2	****	******	******
69JLY	572.50	571.49	1795.	1115.	13.5	11.4	-2.1	-15.4	****	******	******
69AUG	572.26	571.25	1272.	791.	11.9	10.4	-1.5	-12.4	****	******	******
69SEP	571.70	570.68	925.	******	*****	*****	******	******	****	******	******
69OCT	571.23	570.20	5574.	******	*****	*****	******	******	****	******	******
69NOV	570.92	569.89	5334.	3639.	41.0	38.1	-2.9	-7.1	****	******	******
69DEC	570.96	569.51	2254.	******	*****	*****	******	******	****	******	******
70JAN	570.49	569.43	9153.	******	*****	*****	******	******	****	******	******
70FEB	570.70	569.61	8677.	******	*****	*****	******	******	****	******	******
70MAR	570.55	569.74	4105.	3456.	34.8	33.5	-1.3	-3.8	29.	5.8	16.7
70APR	571.05	570.29	5675.	5322.	40.1	37.3	-2.8	-6.9	64.	-23.9	-59.7
70MAY	571.36	570.80	5395.	5597.	17.0	15.9	-1.1	-6.0	21.	-3.1	-17.0
70JUN	571.59	571.11	3317.	2732.	15.0	14.5	-.5	-3.2	17.	-2.0	-13.0
70JLY	571.56	571.16	1357.	1636.	14.0	13.0	-1.0	-7.2	16.	-2.0	-14.0
70AUG	571.40	571.04	679.	564.	11.1	10.7	-.4	-3.5	10.	.1	.8
70SEP	571.16	570.83	1347.	******	*****	*****	******	******	****	******	******
70OCT	571.05	570.65	3241.	******	*****	*****	******	******	****	******	******
70NOV	570.95	570.40	28912.	24770.	83.3	75.9	-7.4	-8.9	83.	.3	.3
70DEC	571.03	570.35	13661.	******	*****	*****	******	******	****	******	******
71JAN	570.93	570.17	11733.	******	*****	*****	******	******	****	******	******
71FEB	570.89	570.05	21726.	******	*****	*****	******	******	****	******	******
71MAR	571.42	570.53	10726.	7301.	48.4	42.5	-5.8	-12.0	48.	.4	.8
71APR	571.60	570.67	6093.	4414.	39.0	35.6	-3.4	-8.8	29.	9.3	25.4
71MAY	571.67	570.71	7035.	4008.	18.1	16.4	-1.7	-9.3	15.	3.1	17.3
71JUN	571.82	570.83	762.	437.	13.0	12.7	-.3	-2.1	15.	-2.1	-16.0
71JLY	571.66	570.65	2405.	1572.	15.4	12.9	-2.6	-15.6	21.	-5.6	-36.5
71AUG	571.50	570.47	1073.	557.	11.3	10.0	-1.2	-11.0	12.	-.7	-6.3
71SEP	571.49	570.45	736.	******	*****	*****	******	******	****	******	******
71OCT	571.58	570.53	1719.	******	*****	*****	******	******	****	******	******
71NOV	571.19	570.13	6464.	4257.	43.1	33.1	-4.0	-9.2	42.	1.1	2.5

EVALUATION FOR PLAN 77 CAT 1 25,000

TIME	WATER LEVELS FDC	WATER LEVELS TCFS	CALCULATED WAVE ENERGY FDC	CALCULATED WAVE ENERGY TCFS	PREDICTED TURBIDITY FDC	PREDICTED TURBIDITY TCFS	DIFF	% DIFF	OBS	O:SDIFF	%DIFF
72JAN	571.22	570.15	23776.	******	*****	*****	******	******	****	******	******
72FEB	571.11	570.03	9407.	******	*****	*****	******	******	****	******	******
72MAR	571.49	570.40	17156.	3130.	53.2	45.2	-7.9	-14.9	19.	34.2	64.3
72APR	571.93	570.85	4446.	2331.	35.5	32.4	-3.1	-8.7	37.	-1.5	-4.2
72MAY	572.34	571.27	7567.	4397.	13.6	15.4	-2.1	-11.5	15.	3.6	19.2
72JUN	572.41	571.34	2332.	1797.	14.7	13.9	-.9	-6.4	9.	5.7	38.9
72JLY	572.49	571.42	3265.	2030.	18.0	14.2	-3.8	-21.0	13.	5.0	27.9
72AUG	572.30	571.22	2285.	1271.	15.0	11.9	-3.1	-20.7	14.	1.0	6.8
72SEP	572.13	571.05	2265.	******	*****	*****	******	******	****	******	******
72OCT	572.02	570.92	4515.	******	*****	*****	******	******	****	******	******
72NOV	572.14	571.04	6142.	3326.	42.6	38.5	-4.0	-9.5	48.	-5.4	-12.8
72DEC	572.39	571.29	14379.	******	*****	*****	******	******	****	******	******
73JAN	572.49	571.40	22616.	******	*****	*****	******	******	****	******	******
73FEB	572.47	571.38	5465.	******	*****	*****	******	******	****	******	******
73MAR	572.77	571.68	11359.	7966.	50.7	42.5	-8.2	-16.1	55.	-4.3	-8.5
73APR	573.30	572.22	14207.	9349.	55.5	45.5	-10.0	-17.9	56.	-.5	-.9
73MAY	573.33	572.26	17397.	11743.	26.7	22.0	-4.7	-17.5	26.	.7	2.7
73JUN	573.60	572.53	4572.	5118.	19.4	15.5	-2.9	-14.8	23.	-3.6	-18.5
73JLY	573.49	572.42	5121.	3233.	24.3	17.9	-6.4	-26.3	29.	-4.7	-19.2
73AUG	573.20	572.12	1766.	966.	13.4	11.0	-2.5	-19.3	7.	6.4	47.8
73SEP	572.74	571.66	2213.	******	*****	*****	******	******	****	******	******
73OCT	572.39	571.30	2373.	******	*****	*****	******	******	****	******	******
73NOV	572.10	571.03	9342.	6094.	48.2	42.4	-5.8	-12.0	42.	6.2	12.9
73DEC	572.14	571.04	20123.	******	*****	*****	******	******	****	******	******
74JAN	572.28	571.18	16065.	******	*****	*****	******	******	****	******	******
74FEB	572.63	571.54	14241.	******	*****	*****	******	******	****	******	******
74MAR	573.11	572.02	15641.	10336.	53.6	48.3	-9.7	-16.6	52.	6.6	11.2
74APR	573.40	572.33	27064.	18901.	81.9	65.1	-16.7	-20.4	61.	20.9	25.5
74MAY	573.47	572.40	13125.	9417.	23.8	20.1	-3.7	-15.4	25.	-1.2	-5.2
74JUN	573.49	572.42	15690.	10347.	25.3	20.9	-4.4	-17.5	16.	9.3	36.8
74JLY	573.26	572.20	4371.	2717.	21.4	16.3	-5.1	-23.9	19.	2.4	11.3
74AUG	572.90	571.82	4706.	2325.	22.4	17.0	-5.5	-24.4	5.	7.4	33.2
74SEP	572.47	571.38	4581.	******	*****	*****	******	******	****	******	******
74OCT	572.05	570.96	6649.	******	*****	*****	******	******	****	******	******
74NOV	571.96	570.85	7414.	4617.	44.8	39.9	-4.9	-10.8	45.	-.2	-.5
74DEC	572.13	571.02	4443.	******	*****	*****	******	******	****	******	******
75JAN	572.28	571.17	23294.	******	*****	*****	******	******	****	******	******
75FEB	572.41	571.31	5792.	******	*****	*****	******	******	****	******	******
75MAR	572.81	571.71	6695.	4336.	40.1	35.3	-4.8	-12.1	59.	-18.9	-47.0
75APR	572.85	571.76	10499.	7364.	47.9	41.5	-6.4	-13.4	38.	9.9	20.7
75MAY	572.90	571.81	2741.	1547.	14.6	13.6	-1.0	-6.6	9.	5.6	38.2
75JUN	573.00	571.91	10369.	6394.	20.9	17.9	-2.9	-14.1	19.	1.9	9.0
75JLY	572.83	571.74	2167.	1263.	14.6	11.3	-2.8	-18.8	16.	-1.4	-9.3
75AUG	572.64	571.64	1120.	579.	11.4	9.8	-1.7	-14.5	9.	2.4	21.3
75SEP	572.68	571.64	2016.	******	*****	*****	******	******	****	******	******
75OCT	572.33	571.40	6517.	******	*****	*****	******	******	****	******	******
75NOV	572.03	571.15	19233.	14600.	65.9	57.6	-8.3	-12.6	66.	-.1	-.1
75DEC	572.07	571.17	9950.	******	*****	*****	******	******	****	******	******
76JAN	571.95	571.03	15309.	******	*****	*****	******	******	****	******	******
76FEB	572.00	571.14	20331.	******	*****	*****	******	******	****	******	******
76MAR	573.07	572.36	42349.	26320.	93.9	80.4	-13.6	-14.4	107.	-13.1	-13.9
76APR	573.15	572.45	2414.	1719.	31.3	29.9	-1.4	-4.5	30.	1.3	4.3
76MAY	573.22	572.41	11339.	9593.	21.7	19.4	-2.3	-10.7	28.	-6.3	-29.2
76JUN	573.09	572.24	6746.	4737.	17.9	16.3	-1.6	-9.1	22.	-4.1	-23.0
76JLY	573.06	572.14	2297.	1423.	15.0	12.4	-2.5	-17.2	18.	-3.0	-20.3
76AUG	572.48	571.44	415.	405.	10.6	9.4	-1.1	-10.7	10.	.6	5.3
76SEP	572.33	571.34	1144.	******	*****	*****	******	******	****	******	******
76OCT	571.95	571.05	4512.	******	*****	*****	******	******	****	******	******
76NOV	571.47	570.68	5237.	3173.	41.2	34.6	-2.5	-6.2	36.	5.2	12.5
76DEC	571.08	570.45	6146.	******	*****	*****	******	******	****	******	******
MEANS					22.3	19.5			31.		
PERCENTAGE DIFFERENCE							-3.4	-11.0		1.0	7.8
							3.10	6.08		8.56	23.82

ANNEX 2

Program FOREK

Calculates quantity of water exchange between lake and embayment

```
      PROGRAM FOREK(INPUT,OUTPUT,TAPE60=INPUT,TAPE61=OUTPUT)
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C  THIS IS FOREK NO. 1                                                  C
C                                                                       C
C  PROGRAM TO CALCULATE THE QUANTITY OF WATER EXCHANGED BETWEEN        C
C  EMBAYMENTS AND LAKE.                                                 C
C                                                                       C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
      REAL K,N,L,M
      DIMENSION AH(720),AL(720),TM(720),TV(720),CONC(720),CH(720)
      DIMENSION TITLE(20), WLLOW(72), WLNOR(72), WLHIGH(72)
      DIMENSION DATUM(4), DIFF(72), WLNO(72)
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C  AREA = AREA OF THE EMBAYMENT.                   (METRES**2)          C
C  DDV = DEAD VOLUME OF EMBAYMENT.                 (METRES**3)          C
C  TP = TIME PERIOD                                (SECONDS)            C
C  QL = CONCENTRATION OF THE LAKE WATER.           (MG/L)               C
C  QS = TOTAL MASS ENTERING FROM LANDWARD SIDE.    (MG)                 C
C  QO = INITIAL CONCENTRATION OF WATER IN EMBAYMENT.(MG/L)              C
C  QF = INFLOW INTO HARBOUR FROM LANDWARD SIDE.    (METRES**3/HOUR)     C
C  CH = CHANNEL DEPTH.                             (METRES)             C
C  M = LOSS COEFFICIENT.                                                C
C  R = HYDRAULIC RADIUS.                           (METRES)             C
C  AC = CROSS-SECTIONAL AREA OF CHANNEL.           (METRES**2)          C
C  L = LENGTH OF CHANNEL.                          (METRES)             C
C  W = BOTTOM WIDTH.                               (METRES)             C
C  G = GRAVITATIONAL CONSTANT.                     (METRES/(SEC**2))    C
C  N = ROUGHNESS COEFFICIENT.                                           C
C  NUM = NUMBER OF LAKE LEVEL DATA POINTS.                              C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
      READ (60,88) (TITLE(JJ),JJ=1,20)
      READ (60,2) AREA, DDV, L, W
      READ (60,2) M, N, CH(1), G
      READ (60,1) TP
      READ (60,2) QL, QS, QO, QF
      READ (60,99) NUM
      READ (60,10) DATUM(1), DATUM(2), DATUM(3), DATUM(4)
      DO 22 I=1,NUM
      READ (60,10) WLLOW(I), WLNOR(I), WLHIGH(I), WLNO(I)
```

```
 22   CONTINUE
      DO 23 J=1,NUM
      DIFF(J) = WLNOR(J)-DATUM(2)
      AL(J) = WLNOR(J)
      CH(J) = CH(1)+DIFF(J)
 23   CONTINUE
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC

C  ESTABLISH THE INITIAL TOTAL MASS                                      C

C                        TOTAL VOLUME                                    C

C                        CONCENTRATION OF EMBAYMENT.                     C

C  ASSUME LAKE AND EMBAYMENT LEVELS ARE EQUAL AT TIME ZERO.              C

C  INITIALLY ASSUME CHANNEL BOTTOM TO BE CH(1) METRES BELOW DATUM.       C

CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC

      TV(1) = DDV+(CH(1)*AREA)
      TM(1) = TV(1)*QO*1000.0
      CONC(1) = QO
C  CONCENTRATION EXPRESSED IN MG/L.
C
      AH(1) = AL(1)
      WRITE (61,85) (TITLE(JJ),JJ=1,20)
      WRITE (61,11)
      WRITE (61,12) AREA, DDV, CH(1), L, W, M, N
      WRITE (61,13)
      WRITE (61,14) QO, QL, QS, QF
      WRITE (61,15) TF
      WRITE (61,16)
      WRITE (61,89)
      DO 900 I=1,NUM
C  ASSUME A RECTANGULAR CROSS-SECTIONAL AREA FOR THE CONNECTING CHANNEL.

      AC = CH(I)*W
      WP = W+2*CH(I)
      R = AC/WP
      ALAKE=AL(I+1)
      BAY=AH(I)
      CDSQ=R**1.333/(2.*G*N*N*L+M*R**1.333)
      K=AREA**2/(AC**2*CDSQ*2.*G)
      IF(ALAKE.LT.BAY) K=-K
      CALL FLUSH1(ALAKE,BAY,K,TF,AREA,QF,BAYNEW)
      AH(I+1)=BAYNEW
      T=(AH(I+1)-AH(I))*AREA-QF
      TV(I+1)=TV(I)+T
      IF(AL(I+1)-AH(I)) 399,400,401
 399  TM(I+1)=TM(I)+(T*CONC(I)*1000.0)+QS
      CONC(I+1)=TM(I+1)/(TV(I+1)*1000.0)
      GO TO 21
 400  TM(I+1)=TM(I)+QS
      CONC(I+1)=TM(I+1)/TV(I+1)
      GO TO 21
 401  TM(I+1)=TM(I)+(T*QL*1000.0)+QS
      CONC(I+1)=TM(I+1)/(TV(I+1)*1000.0)
 21   CONTINUE
 24   WRITE(61,17)  I, AL(I), AH(I), TM(I),TV(I),CONC(I)
 900  CONTINUE
 1    FORMAT (F10.5)
 2    FORMAT (4F10.0)
 10   FORMAT (8X,4F 10.4)
 11   FORMAT (T5,'PHYSICAL CONFIGURATION DATA',/,T5
     1,'***************************')
```

```
12   FORMAT (T14,'HARBOUR AREA =',F12.0,' METRES**2',/,
    1T15,'DEAD VOLUME =',F12.0,' METRES**3',/,
    2T5,'INITIAL CHANNEL DEPTH =',F12.2,' METRES',/,
    3T12,'CHANNEL LENGTH =',F12.2,' METRES',/,
    4T13,'CHANNEL WIDTH =',F12.2,' METRES',/,
    5T7,'CONSTRICTION FACTOR =',F12.3,/,
    6T5,'ROUGHNESS COEFFICIENT =',F12.3,/)
13   FORMAT (T5,'INITIAL CONDITION DATA',/,
    1T5,'**********************')
14   FORMAT (T5,'INITIAL HARBOUR CONCENTRATION',F15.3,/,
    1T8,'INITIAL LAKE CONCENTRATION',F15.3,/,
    2T5,'LANDWARD SIDE MASS INPUT/HOUR',F15.3,/,
    3T16,'LANDWARD SIDE FLOW',F15.3,/)
15   FORMAT (T5,'TIME PERIOD =',F10.3,'SECONDS')
16   FORMAT (/,/,/,/)
17   FORMAT (T3,I4,T10,F7.3,T23,F7.3,T35,F15.0,T50,F15.0,T68,F7.3)
85   FORMAT(1H1,4X,/,20A4,/)
88   FORMAT (20A4)
89   FORMAT ('1',T3,'HOUR',T10,'LAKE LEVEL',T23,'HARBOUR LEVEL',
    1T38,'TOTAL MASS',T53,'TOTAL VOLUME',T68,'CONCENTRATION',/)
99   FORMAT(I3)
     STOP
     END
     SUBROUTINE FLUSH1(ALAKE,BAY,C,TP,AREA,QF,BAYNEW)
     ABAY=ALAKE
     I=1
  10 FUN=ALAKE-ABAY-C*((ABAY-BAY)/TP-(QF/AREA))**2
     FUNBAR=(-2.)*C/TP*((ABAY-BAY)/TP-(QF/AREA))-1.
     BAYNEW=ABAY-FUN/FUNBAR
     IF((BAYNEW-ABAY)/BAYNEW .LE.0.0001) GO TO 20
     ABAY=BAYNEW
     I=I+1
     IF(I.GT.20) GO TO 30
     GO TO 10
  20 IF(BAYNEW.GT.ALAKE) BAYNEW=ALAKE
     RETURN
  30 PRINT 40
  40 FORMAT(1H ,10X,44HCONVERGENCE NOT ACHIEVED AFTER 20 ITERATIONS)
     RETURN
     END
```

Example input data

```
              ***  MENTOR  HARBOUR   ***
29200.0000 15756.000      221.00       53.00
    1.000      0.020        1.00        9.81
3600.0
25.0        270000.0   25.450      3.60
 72
DATUM       174.3212   173.8945   173.7604
  1         174.3212   173.8945   173.7604
  2         174.3303   173.9036   173.8549
  3         174.3242   173.8549   174.0134
  4         174.3456   173.8305   174.1779
  5         174.3425   173.7634   174.2237
  6         174.3364   173.7756   174.2999
  7         174.3303   173.8274   174.4248
  8         174.3486   173.8427   174.4614
  9         174.3364   173.8579   174.4523
 10         174.3273   173.9006   174.4858
 11         174.3456   173.9432   174.7693
 12         174.3639   173.9798   175.7019
 13         174.3547   174.0042   175.6684
 14         174.3547   174.0377   176.2079
 15         174.3425   174.0347   176.2232
 16         174.3517   174.0377   176.1683
 17         174.3303   174.0530   176.1378
 18         174.3273   174.0774   176.2201
 19         174.3486   174.0835   176.2049
 20         174.3425   174.0713   176.2018
 21         174.3547   174.0347   176.1744
 22         174.3608   174.0438   176.1713
 23         174.3730   174.0408   176.1195
 24         174.3639   174.0438   176.0494
 25         174.3730   174.0408   175.9397
 26         174.3639   174.0682   175.4398
 27         174.3425   174.0621   174.7784
 28         174.3547   174.0316   174.4766
 29         174.3486   174.0621   174.2541
 30         174.3425   174.0956   174.1840
 31         174.3425   174.0865   174.0865
 32         174.3364   174.1536   174.0774
 33         174.3425   174.3547   174.1597
 34         174.3364   174.4431   174.1261
 35         174.3364   174.3700   174.0621
 36         174.3303   174.3121   174.1292
 37         174.3425   174.2420   174.2359
 38         174.3608   174.2298   174.1932
 39         174.3608   174.1840   174.2176
 40         174.3547   174.1536   174.2633
 41         174.3639   174.2023   174.2602
 42         174.3486   174.1840   174.1779
 43         174.3395   174.1353   174.1170
 44         174.3486   174.1871   174.1536
 45         174.3425   174.2389   174.1444
 46         174.3486   174.2328   174.0865
 47         174.3608   174.1993   174.0560
 48         174.3669   174.2602   174.1109
 49         174.3639   174.3486   174.1322
 50         174.3669   174.3913   174.1292
 51         174.3578   174.3822   174.1871
 52         174.3395   174.3242   174.1993
 53         174.3334   174.2816   174.1718
 54         174.3273   174.1962   174.1139
 55         174.3182   174.1109   174.1109
 56         174.3273   174.0530   174.1040
 57         174.3303   174.0560   174.0560
 58         174.3303   174.1017   174.0286
 59         174.3456   174.1261   174.0194
 60         174.3578   174.1139   174.0377
 61         174.3669   174.1779   174.0225
 62         174.3791   174.2816   174.0774
 63         174.3852   174.3578   174.1170
 64         174.3822   174.2724   174.1353
 65         174.3883   174.3182   174.1597
 66         174.3791   174.2846   174.1871
 67         174.3669   174.1901   174.1810
 68         174.3486   174.1048   174.1718
 69         174.3334   174.0682   174.1505
 70         174.3212   174.0408   174.0987
 71         174.3364   174.0042   174.0408
 72         174.3334   173.9676   174.0194
```

Example output

```
      ***  MENTOR  HARBOUR  ***

PHYSICAL CONFIGURATION DATA
**********************
         HARBOUR AREA =      29200. METRES**2
          DEAD VOLUME =      15756. METRES**3
INITIAL CHANNEL DEPTH =       1.00 METRES
       CHANNEL LENGTH =     221.00 METRES
        CHANNEL WIDTH =      53.00 METRES
  CONSTRICTION FACTOR =      1.000
ROUGHNESS COEFFICIENT =       .020

INITIAL CONDITION DATA
**********************
INITIAL HARBOUR CONCENTRATION         25.450
   INITIAL LAKE CONCENTRATION         25.000
LANDWARD SIDE MASS INPUT/HOUR     270000.000
           LANDWARD SIDE FLOW          3.600

TIME PERIOD =  3600.000SECONDS
```

Example output

HOUR	LAKE LEVEL	HARBOUR LEVEL	TOTAL MASS	TOTAL VOLUME	CONCENTRATION
1	173.895	173.895	1144130200.	44956.	25.450
2	173.904	173.903	1150487030.	45199.	25.454
3	173.855	173.855	1114944059.	43792.	25.460
4	173.831	173.831	1096982866.	43076.	25.466
5	173.763	173.763	1047265179.	41113.	25.473
6	173.776	173.775	1055663567.	41439.	25.475
7	173.827	173.827	1093803216.	42953.	25.465
8	173.843	173.842	1105143895.	43396.	25.466
9	173.858	173.857	1116444726.	43837.	25.468
10	173.901	173.900	1147881550.	45084.	25.461
11	173.943	173.943	1179210135.	46326.	25.454
12	173.980	173.979	1206140574.	47393.	25.450
13	174.004	174.004	1224145520.	48102.	25.449
14	174.038	174.037	1248815105.	49078.	25.445
15	174.035	174.035	1247079067.	48999.	25.451
16	174.038	174.037	1249117486.	49070.	25.456
17	174.053	174.053	1260487689.	49514.	25.457
18	174.077	174.077	1278503491.	50224.	25.456
19	174.084	174.083	1283128350.	50398.	25.460
20	174.071	174.071	1274537033.	50050.	25.465
21	174.035	174.035	1247500196.	48978.	25.471
22	174.044	174.043	1254000738.	49227.	25.474
23	174.041	174.041	1252276096.	49149.	25.479
24	174.044	174.043	1254319397.	49220.	25.484
25	174.041	174.041	1252598273.	49142.	25.490
26	174.068	174.068	1272488770.	49926.	25.487
27	174.062	174.062	1268424402.	49756.	25.493
28	174.032	174.032	1245898804.	48862.	25.498
29	174.062	174.062	1268050124.	49737.	25.495
30	174.096	174.095	1292710405.	50713.	25.491
31	174.087	174.087	1286388912.	50454.	25.496
32	174.154	174.153	1335337854.	52402.	25.483
33	174.355	174.355	1482458686.	58276.	25.439
34	174.443	174.443	1547137178.	60852.	25.425
35	174.370	174.370	1493157888.	58718.	25.429
36	174.312	174.312	1450343673.	57024.	25.434
37	174.242	174.242	1398460845.	54973.	25.439
38	174.230	174.230	1389576924.	54614.	25.444
39	174.184	174.184	1355727796.	53273.	25.449
40	174.154	174.154	1333315721.	52381.	25.454
41	174.202	174.202	1368844135.	53792.	25.447
42	174.184	174.184	1355630798.	53262.	25.452
43	174.135	174.135	1319615102.	51836.	25.457
44	174.187	174.187	1357401522.	53337.	25.450
45	174.239	174.239	1395417752.	54847.	25.442
46	174.233	174.233	1391253031.	54672.	25.447
47	174.199	174.199	1366539068.	53691.	25.452
48	174.260	174.260	1411003443.	55458.	25.443
49	174.349	174.348	1475756830.	58038.	25.428
50	174.391	174.391	1507097757.	59281.	25.423
51	174.382	174.382	1500664494.	59017.	25.428
52	174.324	174.324	1457778545.	57320.	25.432
53	174.282	174.282	1426321062.	56072.	25.437
54	174.196	174.196	1363067103.	53575.	25.442
55	174.111	174.111	1299874849.	51080.	25.448
56	174.053	174.053	1257029515.	49386.	25.453
57	174.056	174.056	1259082277.	49458.	25.458
58	174.102	174.101	1292684216.	50791.	25.451
59	174.126	174.126	1310676681.	51500.	25.450
60	174.114	174.114	1302049127.	51150.	25.455
61	174.178	174.178	1348744738.	53007.	25.445
62	174.282	174.281	1424687913.	56034.	25.425
63	174.358	174.358	1480501450.	58256.	25.414
64	174.272	174.272	1417442944.	55764.	25.419
65	174.318	174.318	1450896032.	57091.	25.414
66	174.285	174.285	1426304274.	56113.	25.418
67	174.190	174.190	1356343056.	53350.	25.424
68	174.105	174.105	1293197631.	50856.	25.429
69	174.068	174.068	1266199783.	49783.	25.434
70	174.041	174.041	1246028778.	48980.	25.440
71	174.004	174.004	1219019203.	47907.	25.445
72	173.968	173.968	1192003584.	46835.	25.451

ANNEX 3

Program ONTARIO

Calculates annual *Cladophora* production
for BOC and Plan

```
      PROGRAM ONTARIO (INPUT,OUTPUT,TAPE60=INPUT,TAPE61=OUTPUT,TAPE10=0)
     DIMENSION ELEV(59), AREA(59), BOC(77), PLAN(77)
     1, TOBOC(79), TOPLAN(79), DIFF(79),YEAR(79),PERDIFF(79)
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C NAREA    = NUMBER OF POINTS DEFINING THE ELEVATION / AREA RELATIONSHIP,   C
C ELEV     = ARRAY OF LAKE ELEVATIONS                                        C
C AREA     = AREA IN ACRES AT ELEVATION ELEV                                 C
C BOC      = BOC WATER ELEVATION                                             C
C PLAN     = PLAN WATER ELEVATION                                            C
C TOBOC    = TOTAL CLADOPHORA PRODUCTION FOR YEAR                            C
C TOPLAN   = TOTAL CLADOPHORA PRODUCTION FOR YEAR FOR PLAN ELEVATION         C
C DIFF     = DIFFERENCE BETWEEN ANNUAL BOC AND PLAN PRODUCTION               C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
      READ (60,99) NAREA
C  WATER LEVELS AND AREAS READ FROM HWL.
      WRITE (61,98)
      DO 1 I=1,NAREA
      READ (60,100) ELEV(I), AREA(I)
      WRITE (61,101) ELEV(I), AREA(I)
 1    CONTINUE
C READ MAY BOC WATER LEVELS FOR 77 YEARS.
      DO 3 I=1,77
      READ (60,104) BOC(I)
 3    CONTINUE
C READ MAY PLAN WATER LEVELS FOR 77 YEARS.
      DO 4 I=1,77
      READ (60,105) PLAN(I)
 4    CONTINUE
      WRITE (61,106)
      SUMBOC=SUMPLAN=SUMDIFF=0.0
      IMAX=IMIN=0
      XMAX=XMIN=0.0
      DO 5 I=1,77
      CALL EST (ELEV,AREA,NAREA,TOBOC(I),BOC(I))
      CALL EST (ELEV,AREA,NAERA,TOPLAN(I),PLAN(I))
      DIFF(I) = TOPLAN(I)-TOBOC(I)
      PERDIFF(I)=(DIFF(I)/TOBOC(I))*100.0
      SUMBOC=SUMBOC+TOBOC(I)
      SUMPLAN=SUMPLAN+TOPLAN(I)
      SUMDIFF=SUMDIFF+DIFF(I)
      IF(DIFF(I).GT.XMAX) IMAX=I
      IF(DIFF(I).GT.XMAX) XMAX=DIFF(IMAX)
      IF(DIFF(I).LT.XMIN) IMIN=I
      IF(DIFF(I).LT.XMIN) XMIN=DIFF(IMIN)
      IYEAR = 1899+I
      YEAR(I)=FLOAT(IYEAR)
      WRITE (61,107)IYEAR, BOC(I), PLAN(I), TOBOC(I), TOPLAN(I), DIFF(I)
 5    CONTINUE
      CALL PLOT(0.,1.5,-3)
      CALL AXIS(0.,0.,5HYEARS,-5,8.,0.,1900.,+10.)
      CALL PLOT(0.,1.75,-3)
      CALL AXIS(0.,0.,20HPRODUCTION TONS/YEAR,+20,4.,90.,12500.,+750,)
      YEAR(78)=1900.0
      YEAR(79)=10.0
      TOPLAN(78)=12500.
      TOPLAN(79)=750.0
      CALL LINE(YEAR,TOPLAN,77,1,0,0)
      CALL SYMBOL (1.,-2.5,0.14,48HFIGURE      :ONTARIO BASIN CLADOPHORA
     1 PRODUCTION,0.,48)
      CALL SYMBOL(3.5,-2.75,0.14,16HFOR BOC AND PLAN,0.,16)
      CALL PLOT(8.,-0.75,-3)
```

```
      CALL PLOT(0.,0.5,3)
      CALL PLOT(.1,0.5,2)
      CALL NUMBER(.15,0.5,.1,2.0,0.,1)
      CALL PLOT(0.,0.5,3)
      CALL PLOT(0.,0.,2)
      CALL PLOT(.1,0.,2)
      CALL NUMBER(.15,.0,.1,0.,0.,1)
      CALL PLOT(0.,0.,3)
      CALL PLOT(0.,-0.5,2)
      CALL PLOT(.1,-0.5,2)
      CALL NUMBER(.15,-0.5,.1,-2.0,0.,1)
      CALL SYMBOL(0.75,-0.75,0.14,17H% CHANGE FROM BOC,90.,17)
      CALL PLOT(0.,0.,3)
      CALL PLOT(-8.0,0.,-2)
      PERDIFF(78)=0.0
      PERDIFF(79)=4.0
      CALL LINE(YEAR,PERDIFF,77,1,0,0)
      CALL PLOT(8.,0.,999)
      XMEBOC=SUMBOC/77.0
      XMEPLAN=SUMPLAN/77.0
      XMEDIFF=SUMDIFF/77.0
      PERME=(XMEDIFF/XMEBOC)*100.0
      WRITE (61,108) XMEBOC, XMEPLAN, XMEDIFF, PERME
      PERINC=(DIFF(IMAX)/TOBOC(IMAX))*100.0
      IMAYR=1899+IMAX
      PERDEC=(DIFF(IMIN)/TOPLAN(IMIN))*100.0
      IMIYR=1899+IMIN
      WRITE (61,110)IMAYR, TOBOC(IMAX), TOPLAN(IMAX), DIFF(IMAX), PERINC
      WRITE (61,111) IMIYR, TOBOC(IMIN), TOPLAN(IMIN), DIFF(IMIN),PERDEC
 98   FORMAT ('1',9X,'ELEVATION VERSUS AREA DEFINING CURVE',/,
     $15X,'ELEVATION',8X,'AREA',/,18X,'FEET',11X,'ACRES')
 99   FORMAT (2X,I4)
 100  FORMAT (2X,F5.2,2X,F5.0)
 101  FORMAT (17X,F6.2,10X,F5.0)
 104  FORMAT (24X,F6.2)
 105  FORMAT (24X,F6.2)
 106  FORMAT ('1',15X,'CLADOPHORA PRODUCTION FOR BOC AND PLAN',//,
     $9X,'YEAR',11X,'LEVELS',21X,'PRODUCTION',/,
     $24X,'(FEET)',20X,'(TONS/YEAR)',/,
     $18X,'*****************',6X,'********************************',/,
     $20X,'BOC',7X,'PLAN',8X,'BOC',9X,'PLAN',6X,'PLAN-BOC',/,
     $9X,'*************************************************************
     $*')
 107  FORMAT (9X,I4,5X,F6.2,5X,F6.2,4X,F8.0,4X,F8.0,4X,F8.0)
 108  FORMAT (9X,'MEAN VALUES',21X,F6.0,6X,F6.0,6X,F6.0,2X,F5.1)
 110  FORMAT (2X,'MAXIMUN INCREASE',/,
     $2X,I4,5X,F8.0,5X,F8.0,5X,F8.0,5X,F5.1)
 111  FORMAT (2X,'MAXIMUN DECREASE',/,
     $2X,I4,5X,F8.0,5X,F8.0,5X,F8.0,5X,F5.1)
      STOP
      END
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
      SUBROUTINE EST(ELEV,AREA,NAREA,TOT,DATUM)
      DIMENSION ELEV(NAREA),AREA(NAREA)
      DO 200 I=1,100
      K=I
      IF(DATUM.GT.ELEV(1)) GO TO 303
      IF(DATUM.EQ.ELEV(I)) GO TO 201
      IF(DATUM.GT.ELEV(I)) GO TO 202
 200  CONTINUE
 201  TOT = AREA(K)*2.0
      GO TO 302
 202  PRO=(DATUM-ELEV(K))/(ELEV(K-1)-ELEV(K))
      AA = (AREA(K-1)-AREA(K))*PRO+AREA(K-1)
      TOT = AA*2.0
 301  CONTINUE
      GO TO 302
 303  WRITE (61,100)
 100  FORMAT (2X,'FLAG')
 302  RETURN
      END
```

EXAMPLE: Input data, Lake Ontario Northshore

FIGURE :LAKE ONTARIO NORTHSHORE CLADOPHORA
PRODUCTION FOR PLAN 6L
59 PLAN 77 6L

24750	6410
24740	6446
24730	6482
24720	6518
24710	6554
24700	6590
24690	6626
24680	6662
24670	6698
24660	6734
24650	6770
24640	6806
24630	6842
24620	6878
24610	6914
24600	6950
24590	6986
24580	7022
24570	7058
24560	7094
24550	7130
24540	7166
24530	7202
24520	7238
24510	7274
24500	7310
24490	7346
24480	7382
24470	7418
24460	7454
24450	7490
24440	7526
24430	7562
24420	7598
24410	7634
24400	7670
24390	7700
24380	7740
24370	7775
24360	7815
24350	7850
24340	7885
24330	7925
24320	7960
24310	8000
24300	8025
24290	8055
24280	8075
24270	8085
24260	8085
24250	8080
24240	8080
24230	8075
24220	8070
24210	8070
24200	8065
24190	8060
24180	8055
24170	8050

Total Area Available for Production versus Lake Level.

Lake Ontario BOC water levels.

244.29244.38244.52245.21245.57245.76245.95246.04245.65245.04244.54244.58	1900
244.22243.97243.89245.15245.64245.74245.55245.22244.84244.21243.72243.76	1901
243.91243.74244.31244.87245.06245.49246.29246.18245.35244.59243.99243.62	1902
243.58243.81244.54245.50245.43245.29245.52245.40244.90244.30243.72243.35	1903
243.08243.38243.96245.37246.06246.36246.27245.80245.11244.44243.71243.26	1904
243.28243.04243.14244.28245.05245.64245.91245.71245.09244.35243.76243.64	1905
244.00244.18243.97244.29244.66245.16245.53245.30244.66244.25244.06243.77	1906
244.26244.40244.17244.58244.98245.38245.54245.41244.85244.46244.13243.84	1907
244.30244.42244.67245.40246.02246.16245.93245.47244.57243.94243.47243.14	1908
243.04243.30243.73244.42245.59245.80245.59245.22244.59243.94243.58243.47	1909
243.43243.56244.12244.62245.28245.50245.43245.26244.87244.35243.77243.50	1910
243.36243.46243.59244.27245.05245.51245.68245.43245.15244.90244.51244.30	1911
244.30244.10244.01244.98245.89246.44246.11245.53245.03244.59244.18243.89	1912
244.42244.89244.74245.81246.05246.06245.75245.29244.68244.14243.84243.62	1913
243.57243.72243.65244.69245.36245.51245.37245.07244.81244.23243.66243.30	1914
243.25243.61243.93244.11244.61244.95245.11245.51245.26244.67243.91243.54	1915
243.90244.12244.04244.91245.66246.46246.53245.64244.66243.96243.61243.47	1916
243.52243.59243.97245.12245.35245.78246.17245.78245.02244.38244.12243.76	1917
243.55243.53244.16244.78244.86245.00245.14244.94244.69244.35244.08243.76	1918
243.98244.00244.06244.62245.54246.15245.85245.22244.60244.06243.73243.49	1919
243.34243.20243.35244.19244.88245.22245.62245.69245.22244.64244.11244.06	1920
244.26244.18244.38244.90245.19245.27245.22244.90244.51244.20243.95243.79	1921
243.68243.70244.09245.02245.59245.72245.86245.32244.68244.07243.55243.14	1922
243.11243.07243.38244.27245.05245.83245.90245.59245.16244.65244.33244.30	1923
244.31244.33244.19244.76245.56245.83245.73245.44244.82244.41243.68243.20	1924
242.88242.87243.71244.29244.50244.61244.58244.41244.10243.73243.68243.69	1925
243.29243.02242.91243.78244.78245.08245.13245.05244.95244.77244.60244.37	1926
244.08243.87243.99244.30244.49245.03245.31245.28244.84244.46244.15244.62	1927
245.17245.32245.13245.51245.72245.78245.99245.81245.06244.40244.07243.97	1928
244.16244.47244.60245.71246.60246.70246.49245.93245.17244.52244.05243.73	1929
244.31245.02245.61246.00246.08246.04245.94245.26244.61243.97243.48243.33	1930
243.24243.15243.24243.85244.57245.21245.29245.07244.74244.35244.06243.92	1931
244.29244.81244.86245.40245.73245.69245.75245.70245.23244.81244.64244.34	1932
244.36244.27244.36245.30245.88245.95245.85245.55245.20244.63244.10243.90	1933
243.86243.67243.54244.18244.80244.96245.01244.63244.28243.98243.56243.24	1934
243.06242.87242.88243.24243.74244.25244.66244.48244.04243.58243.34243.07	1935
242.70242.23242.61244.26244.97245.05244.85244.42244.09243.81243.65243.30	1936
243.54244.03244.09244.44245.34245.86245.94245.58244.94244.41244.28243.99	1937
243.79244.14244.49245.00245.16245.34245.42245.52245.24244.77244.04243.66	1938
243.47243.46243.93244.84245.42245.39245.47245.43245.05244.64244.14243.78	1939
243.48243.13243.02243.95245.18245.72245.70245.26244.70244.35243.97243.96	1940
244.29244.21243.99244.51244.99245.15245.18245.00244.65244.28244.10243.89	1941
243.78243.71244.11245.09245.46245.74245.61245.45244.92244.39244.05243.82	1942
244.17244.34244.51245.06245.99246.86246.64246.08245.23244.39244.11243.62	1943
243.38243.36243.49244.25245.18245.56245.60245.13244.61244.02243.54243.43	1944
243.43243.44244.13245.13245.69246.05245.93245.41244.79244.81244.36244.07	1945
244.20244.25244.40244.29244.31244.85245.07244.88244.43244.12243.90243.57	1946
243.75244.12244.02244.99245.86246.89246.89246.49245.64244.60243.95243.59	1947
243.58243.52244.00245.06245.50245.64245.43245.02244.45243.89243.69243.54	1948
243.72244.08244.37244.78245.01245.10245.15244.82244.46244.14243.66243.47	1949
244.03244.52244.62245.68245.87245.74245.57245.28244.85244.34244.03244.08	1950
244.32244.61245.12246.10246.57246.35246.15245.50244.87244.21243.84243.81	1951
244.32245.09245.42246.21246.53246.63246.20245.60244.94244.27243.68243.69	1952
243.86244.09244.26244.88245.42245.76245.51245.17244.66244.02243.55243.58	1953
243.54243.78244.55245.23245.98245.87245.50244.99244.64244.44244.26244.00	1954
244.46244.48244.90245.75245.89245.64245.32245.03244.50244.32244.21243.63	1955
243.43243.38243.71244.44245.46245.73245.42244.99244.67244.03243.53243.44	1956
243.47243.66243.94244.38244.93245.50245.88245.41244.82244.11243.72243.60	1957
243.78243.78244.02244.76245.48245.83245.88245.77245.60245.13244.57244.13	1958
243.87244.00244.34245.36245.76245.68245.53245.15244.69244.36244.13244.29	1959
244.53244.70244.64245.43246.25246.38245.93245.35244.65244.00243.57243.12	1960
242.75242.44243.12244.01245.12245.61245.62245.23244.76244.09243.48243.19	1961
242.94242.83243.00243.98244.78245.05244.97244.90244.49244.31244.01243.89	1962
243.44243.01242.91243.99244.92245.29245.15244.94244.42243.76243.27243.00	1963
242.55242.28242.30243.13243.97244.37244.39244.09243.63242.90242.25241.87	1964
241.81241.96242.48243.18244.09244.50244.68244.50244.32244.09243.96244.15	1965
244.15244.03244.41244.68244.88245.26245.24244.96244.65244.19243.87244.13	1966
244.23244.31244.23244.98245.65246.08246.30246.05245.48245.07244.90244.57	1967
244.30244.22244.19244.84244.99245.50245.78245.51245.10244.44244.07244.17	1968
244.21244.40244.23244.89245.60246.02245.87245.41244.64244.01243.80243.76	1969
243.69243.75243.84244.57245.21245.43245.63245.38244.84244.50244.21244.18	1970
244.19244.15244.55245.16245.71245.61245.44245.10244.88244.42243.92243.82	1971
244.03244.24244.59245.32246.21246.40246.63246.30245.55244.79244.53244.82	1972
245.49246.03246.35247.27247.38247.22246.60245.74244.90244.32243.95243.98	1973
244.63245.20245.50246.04246.59246.83246.53245.77244.86244.12243.71243.82	1974
244.07244.49245.00245.54245.82245.85245.52245.11244.82244.63244.24244.06	1975
244.27244.56245.67246.58247.03247.02246.67246.05245.27244.71244.11243.71	1976

Lake Ontario Plan 6L water levels.

244.41	244.54	244.71	245.31	245.58	245.60	245.59	245.44	244.92	244.36	243.93	244.01	1900
243.72	243.55	243.37	244.68	245.34	245.58	245.42	245.09	244.68	243.97	243.33	243.30	1901
243.52	243.44	244.10	244.84	245.16	245.68	246.47	246.32	245.48	244.69	244.08	243.77	1902
243.64	243.89	244.74	245.76	245.70	245.51	245.69	245.54	245.01	244.39	243.77	243.40	1903
243.28	243.63	244.15	245.49	246.11	246.40	246.21	245.69	245.02	244.36	243.66	243.27	1904
243.43	243.26	243.41	244.51	245.14	245.69	245.94	245.73	245.09	244.35	243.76	243.64	1905
243.93	244.03	243.86	244.21	244.66	245.15	245.51	245.28	244.51	243.98	243.83	243.67	1906
244.28	244.29	244.06	244.65	245.14	245.57	245.78	245.61	245.00	244.54	244.18	243.86	1907
244.21	244.13	244.27	244.90	245.60	245.92	245.78	245.35	244.46	243.75	243.25	242.82	1908
242.67	242.90	243.39	244.26	245.51	245.75	245.56	245.22	244.59	243.95	243.57	243.57	1909
243.77	243.96	244.46	244.91	245.47	245.50	245.29	245.20	244.92	244.48	243.90	243.58	1910
243.46	243.60	243.82	244.54	245.36	245.83	245.96	245.69	245.37	245.10	244.78	244.66	1911
244.70	244.62	244.60	245.57	246.37	246.88	246.40	245.71	245.15	244.67	244.23	243.89	1912
244.26	244.57	244.52	245.64	245.82	245.82	245.56	245.15	244.57	244.05	243.78	243.60	1913
243.58	243.74	243.67	244.71	245.24	245.26	245.14	244.92	244.72	244.19	243.64	243.24	1914
243.21	243.64	244.01	244.28	244.79	245.13	245.32	245.72	245.44	244.82	244.03	243.62	1915
244.04	244.37	244.41	245.33	246.10	246.90	246.87	245.94	244.90	244.13	243.68	243.50	1916
243.59	243.67	244.01	245.12	245.34	245.76	246.10	245.68	244.94	244.31	244.07	243.76	1917
243.40	243.39	244.15	244.82	244.91	245.03	245.17	244.97	244.73	244.26	243.99	243.76	1918
243.85	243.82	243.96	244.58	245.53	246.13	245.77	245.14	244.39	243.85	243.57	243.29	1919
243.07	242.89	243.03	243.95	244.63	244.98	245.35	245.60	245.36	244.87	244.36	244.12	1920
244.09	244.01	244.17	244.54	244.78	245.08	245.11	244.77	244.42	244.06	243.79	243.75	1921
243.76	243.87	244.36	245.30	245.86	245.94	246.04	245.58	245.04	244.40	243.63	243.20	1922
243.26	243.18	243.47	244.33	245.10	245.87	246.10	245.91	245.58	245.15	244.82	244.78	1923
244.71	244.61	244.42	245.00	245.81	246.03	245.88	245.55	244.91	244.48	243.73	243.24	1924
242.98	243.04	243.96	244.54	244.71	244.83	244.79	244.61	244.30	243.91	243.86	243.82	1925
243.41	243.22	243.20	244.12	245.11	245.41	245.47	245.38	245.29	245.06	244.95	244.81	1926
244.47	244.28	244.40	244.69	244.81	245.29	245.49	245.30	244.74	244.31	244.00	244.42	1927
244.76	244.77	244.57	244.94	245.19	245.35	245.64	245.54	244.85	244.25	243.95	243.83	1928
243.86	244.09	244.33	245.48	246.33	246.42	246.12	245.56	244.87	244.29	243.87	243.67	1929
244.22	244.77	245.38	245.75	245.64	245.52	245.43	244.81	244.23	243.68	243.27	243.11	1930
243.03	242.97	243.09	243.71	244.38	245.05	245.14	244.90	244.52	244.13	243.84	243.72	1931
244.15	244.68	244.74	245.28	245.61	245.63	245.74	245.73	245.34	244.95	244.79	244.55	1932
244.59	244.54	244.67	245.63	246.22	246.28	246.15	245.82	245.44	244.86	244.32	244.15	1933
244.19	244.07	244.03	244.72	245.30	245.44	245.49	245.12	244.75	244.39	243.88	243.58	1934
243.49	243.37	243.47	244.01	244.62	245.07	245.58	245.57	245.22	244.68	244.26	243.91	1935
243.57	243.13	243.55	245.16	245.42	245.53	245.41	244.91	244.54	244.23	244.06	243.73	1936
244.05	244.60	244.63	244.99	245.91	246.38	246.38	245.96	245.26	244.70	244.57	244.27	1937
244.11	244.52	244.82	245.44	245.68	245.72	245.71	245.65	245.09	244.58	243.86	243.52	1938
243.51	243.62	244.00	244.79	245.22	245.21	245.44	245.48	245.05	244.61	244.10	243.64	1939
243.24	242.82	242.68	243.56	244.72	245.43	245.62	245.28	244.83	244.52	244.21	244.23	1940
244.48	244.30	244.10	244.65	245.28	245.52	245.48	245.24	244.86	244.48	244.43	244.48	1941
244.60	244.62	244.97	245.88	246.05	246.17	245.90	245.60	245.04	244.48	244.11	243.86	1942
244.13	244.21	244.40	244.96	245.91	246.72	246.38	245.82	245.05	244.27	244.01	243.58	1943
243.43	243.45	243.55	244.30	245.19	245.42	245.32	244.88	244.49	244.04	243.56	243.39	1944
243.40	243.43	244.19	245.39	246.10	246.46	246.33	245.76	245.05	244.99	244.56	244.26	1945
244.23	244.22	244.42	244.33	244.33	244.86	245.06	244.73	244.18	243.89	243.76	243.51	1946
243.73	244.13	244.10	245.12	245.97	247.02	247.12	246.79	246.02	244.99	244.23	243.76	1947
243.63	243.55	244.03	245.06	245.48	245.47	245.15	244.73	244.18	243.66	243.48	243.32	1948
243.53	243.95	244.29	244.73	244.98	245.08	245.07	244.70	244.29	243.94	243.47	243.29	1949
243.92	244.45	244.56	245.62	245.76	245.79	245.76	245.47	244.99	244.38	244.03	244.01	1950
244.12	244.36	244.97	245.97	246.41	246.15	245.98	245.38	244.77	244.13	243.77	243.79	1951
244.18	244.80	245.18	246.00	246.29	246.34	245.94	245.39	244.78	244.15	243.61	243.67	1952
243.77	243.81	243.85	244.59	245.23	245.67	245.56	245.13	244.49	243.83	243.51	243.55	1953
243.46	243.72	244.49	245.17	245.85	245.73	245.41	244.92	244.61	244.43	244.39	244.22	1954
244.54	244.52	245.03	245.92	246.03	245.72	245.24	244.77	244.20	244.02	243.98	243.52	1955
243.39	243.34	243.66	244.45	245.52	245.78	245.46	245.03	244.70	244.05	243.54	243.43	1956
243.51	243.73	243.99	244.42	245.04	245.61	245.98	245.50	244.88	244.18	243.79	243.66	1957
243.92	243.98	244.28	245.06	245.76	246.12	246.18	246.05	245.85	245.36	244.81	244.36	1958
244.16	244.36	244.69	245.67	246.01	245.87	245.69	245.32	244.85	244.51	244.42	244.63	1959
244.84	245.02	245.01	245.80	246.61	246.70	246.15	245.49	244.74	244.08	243.66	243.28	1960
243.06	242.91	243.74	244.65	245.49	245.69	245.50	244.98	244.59	244.09	243.62	243.40	1961
243.19	243.10	243.32	244.30	245.06	245.34	245.26	245.20	244.79	244.63	244.37	244.29	1962
243.88	243.50	243.44	244.49	245.39	245.75	245.64	245.51	245.03	244.46	244.06	243.83	1963
243.46	243.27	243.30	244.02	244.72	245.09	245.11	244.83	244.41	243.72	243.06	242.57	1964
242.31	242.21	242.50	243.04	243.83	244.11	244.29	244.10	243.88	243.73	243.87	244.06	1965
244.01	243.90	244.27	244.55	244.68	245.04	245.06	244.82	244.56	243.99	243.50	243.65	1966
243.72	243.88	243.92	244.80	245.86	246.40	246.49	246.15	245.45	244.98	244.81	244.50	1967
244.36	244.36	244.20	244.75	244.84	245.26	245.49	245.23	244.85	244.24	243.89	243.99	1968
243.92	244.14	243.99	244.70	245.41	245.85	245.72	245.29	244.53	243.92	243.72	243.70	1969
243.60	243.59	243.51	244.16	244.82	245.14	245.50	245.33	244.80	244.59	244.43	244.35	1970
244.23	244.23	244.64	245.26	245.76	245.62	245.40	245.03	244.80	244.32	243.83	243.74	1971
243.82	243.85	244.10	244.93	245.83	245.99	246.26	245.94	245.24	244.59	244.38	244.62	1972
245.17	245.79	246.21	247.15	247.36	247.44	247.14	246.55	245.77	245.17	244.68	244.53	1973
244.94	245.44	245.77	246.37	246.85	247.04	246.88	246.38	245.60	244.83	244.28	244.23	1974
244.44	244.76	245.25	245.84	246.06	246.11	245.76	245.28	244.82	244.59	244.14	243.95	1975
244.18	244.40	245.35	246.25	246.87	247.14	247.18	246.84	246.09	245.38	244.51	243.72	1976

Example output

ELEVATION VERSUS AREA DEFINING CURVE

ELEVATION FEET	AREA ACRES
247.50	6410.
247.40	6446.
247.30	6482.
247.20	6518.
247.10	6554.
247.00	6590.
246.90	6626.
246.80	6662.
246.70	6698.
246.60	6734.
246.50	6770.
246.40	6805.
246.30	6842.
246.20	6878.
246.10	6914.
246.00	6950.
245.90	6985.
245.80	7022.
245.70	7058.
245.60	7094.
245.50	7130.
245.40	7166.
245.30	7202.
245.20	7238.
245.10	7274.
245.00	7310.
244.90	7346.
244.80	7382.
244.70	7418.
244.60	7454.
244.50	7490.
244.40	7526.
244.30	7562.
244.20	7598.
244.10	7634.
244.00	7670.
243.90	7700.
243.80	7740.
243.70	7775.
243.60	7815.
243.50	7850.
243.40	7885.
243.30	7925.
243.20	7960.
243.10	8000.
243.00	8025.
242.90	3055.
242.80	8075.
242.70	8085.
242.60	8085.
242.50	8080.
242.40	8080.
242.30	8075.
242.20	8070.
242.10	8070.
242.00	8065.
241.90	8060.
241.80	8055.
241.70	8050.

Example output

CLADOPHORA PRODUCTION FOR BOC AND PLAN

YEAR	LEVELS (FEET)		PRODUCTION (TONS/YEAR)		
	BOC	PLAN	BOC	PLAN	PLAN-BOC
1900	245.57	245.58	14138.	14130.	-7.
1901	245.64	245.34	14087.	14303.	216.
1902	245.06	245.16	14505.	14433.	-72.
1903	245.43	245.70	14238.	14116.	-122.
1904	246.06	246.11	13785.	13749.	-36.
1905	245.05	245.14	14512.	14447.	-65.
1906	244.66	244.66	14793.	14793.	0.
1907	244.98	245.14	14562.	14447.	-115.
1908	246.02	245.60	13814.	14189.	374.
1909	245.53	245.51	14123.	14181.	58.
1910	245.23	245.47	14346.	14210.	137.
1911	245.05	245.36	14512.	14289.	-223.
1912	245.89	246.37	13907.	13562.	-346.
1913	246.05	245.82	13792.	13958.	166.
1914	245.36	245.24	14289.	14375.	86.
1915	244.61	244.79	14829.	14699.	-130.
1916	245.66	246.10	14073.	13828.	-245.
1917	245.35	245.34	14296.	14303.	7.
1918	244.86	244.91	14649.	14613.	-36.
1919	245.54	245.53	14159.	14165.	7.
1920	244.89	244.63	14634.	14814.	180.
1921	245.19	244.78	14411.	14706.	295.
1922	245.59	245.86	14123.	13929.	-194.
1923	245.05	245.10	14512.	14549.	36.
1924	245.56	245.81	14145.	13965.	-180.
1925	244.50	244.71	14980.	14757.	-223.
1926	244.78	245.11	14706.	14469.	-236.
1927	244.49	244.81	14915.	14685.	-230.
1928	245.72	245.19	14030.	14411.	382.
1929	246.60	246.33	13468.	13590.	122.
1930	246.08	245.64	13770.	14087.	317.
1931	244.57	244.38	14858.	14994.	137.
1932	245.73	245.61	14022.	14109.	86.
1933	245.88	246.22	13914.	13670.	-245.
1934	244.80	245.30	14764.	14404.	-360.
1935	243.74	244.62	15452.	14822.	-630.
1936	244.97	245.42	14570.	14246.	-324.
1937	245.34	245.91	14303.	13893.	-410.
1938	245.16	245.68	14433.	14059.	-374.
1939	245.42	245.22	14246.	14390.	144.
1940	245.18	244.72	14418.	14750.	331.
1941	244.99	245.28	14555.	14345.	-209.
1942	245.46	246.05	14217.	13792.	-425.
1943	245.99	245.91	13835.	13893.	58.
1944	245.18	245.19	14418.	14411.	-7.
1945	245.69	246.10	14051.	13828.	-223.
1946	244.31	244.33	15045.	15030.	-14.
1947	245.86	245.97	13929.	13850.	-79.
1948	245.50	245.48	14260.	14202.	-58.
1949	245.01	244.98	14541.	14562.	21.
1950	245.87	245.76	13922.	14001.	79.
1951	246.57	246.41	13418.	13533.	115.
1952	246.53	246.29	13446.	13619.	173.
1953	245.42	245.23	14246.	14383.	137.
1954	245.99	245.85	13842.	13936.	94.
1955	245.89	246.03	13907.	13806.	-101.
1956	245.46	245.52	14217.	14174.	-43.
1957	244.93	245.04	14598.	14519.	-79.
1958	245.45	245.76	14202.	14001.	-202.
1959	245.76	246.01	14001.	13821.	-180.
1960	246.25	246.61	13648.	13389.	-259.
1961	245.12	245.49	14462.	14195.	-266.
1962	244.78	245.06	14706.	14505.	-202.
1963	244.92	245.39	14606.	14267.	-338.
1964	243.97	244.72	15298.	14750.	-548.
1965	244.09	243.83	15203.	15376.	173.
1966	244.88	244.68	14634.	14778.	144.
1967	245.65	245.86	14080.	13929.	-151.
1968	244.99	244.84	14555.	14663.	108.
1969	245.60	245.41	14188.	14253.	65.
1970	245.21	244.82	14397.	14678.	281.
1971	245.71	245.76	14037.	14001.	-36.
1972	246.21	245.83	13677.	13950.	274.
1973	247.38	247.36	12834.	12849.	14.
1974	246.59	246.85	13403.	13216.	-187.
1975	245.82	246.06	13958.	13765.	-173.
1976	247.03	246.87	13086.	13202.	115.

MEAN VALUES 14253. 14202.
MAXIMUN INCREASE
1928 14030. 14411. 382. 2.7
MAXIMUN DECREASE
1935 15452. 14822. -630. -4.3

ANNEX 4

Wildlife of the Great lakes Region

Waterfowl

Species	Remarks
Mute swan (*Cygnus olor*)	Introduced as domestic variety but some exist in wild state.
Whistling swan (*Cygnus columbianus*)	Most of the North American population migrates through the Great Lakes.
Lesser snow goose (*Anser c. Caerulescens*)	Migrants found in all the Lakes in Fall; Spring usually in Lake Ontario.
Greater snow goose (*Anser caerulescens*)	Migrating geese stop along St. Lawrence River mainly around Quebec City.
Canada goose (*Branta canadensis*)	Most common goose; some nesting in the area.
Atlantic brant (*Branta bernicla*)	Migrate through Lake Ontario and St. Lawrence River.
Wood duck (*Aix sponsa*)	Nest in flooded woods in tree cavities or nest boxes.
European wigeon (*Anas penolope*)	Some sightings reported for Lakes Erie and Ontario but rare.
American wigeon (*Anas americana*)	Common migrant, some nest in area.
Gadwall (*Anas strepera*)	Migrate through Lakes St. Clair and Erie, some nesting in the area.
Green-winged teal (*Anas crecca*)	Common migrant.
Blue-winged teal (*Anas discors*)	Common migrant and nesting species.
Mallard (*Anas Platyrhychos*)	Most common duck in the area.
Black (*Anas rubripes*)	Common migrant; winter in Lakes Erie and St. Clair. Nest in area.
Pintail (*Anas acuta*)	Common migrant especially in western Lake Erie and Lake St. Clair.
Shoyeler (*Anas clypeata*)	Migrant; some nest in area. Found in shallow or deep water.
Canvasback (*Aythya valisineria*)	Common migrant in Lake St. Clair and Lake Erie (important staging area).

Redhead (Aythya americana)	Common migrant; Lakes St. Clair and Erie important staging areas.
Ringnecked (Aythya collaris)	Many nesting in Great Lakes Region. Common migrant.
Tufted (Aythya fuligula)	Rare; sightings reported on Lake Ontario.
Greater scaup (Aythya marila)	Common migrant especially Lake Ontario and St. Lawrence River.
Lesser scaup (Aythya affinis)	A few nest in area; concentrate in Lake St. Clair in Fall.
Oldsquaw (Clangula hyemalis)	Winter throughout area.
Harlequin (Histrionicus histrionicus)	Some reported wintering in Lake Erie; very rare inland.
Bufflehead (Bucephala albeola)	Common migrant.
Barrows goldeneye (Bucephala islandica)	A few isolated records on Lake Ontario.
Common goldeneye (Bucephala clangula)	Overwinter in the area.
Hooded merganser (Mergus cucullatus)	Breed in Great Lakes Area. Fish eaters.
Red Breasted merganser (Mergus serrator)	May overwinter in Great Lakes; some nesting also.
Common merganser (Mergus merganser)	Common nesting and overwintering.
Ruddy (Oxyura jamaicensis)	Common migrant, some nesting in the area.

Other Wetland Avifauna

Species	Remarks
Common loon (Gavia immer)	Some nesting in the area. Fish eaters.
Red Throated loon (Gavia stellata)	Some winter in Lower Lakes.
Red-necked grebe (Podiceps grisegena)	Occasional migrants seen. Not common inland.
Horned grebe (Podiceps auritus)	Winter in Great Lakes area. Eat fish and other small animals.
Pied-billed grebe (Podilymbus podiceps)	Next in area.
White Pelican (Pelecanus erythrorhynchos)	Possibly some nesting in Great lakes and some migrants.
Double-crested cormorant (Phalacrocorax auritus)	Some migrants through area. A few nesting in the region.
Common gallinule (Gallinula chloropus)	Nest in the area near or in water.
American coot (Fulica americana)	Common nesting in some areas. Migrant.

Great blue heron (Ardea herodias)	Nest in rookeries; common; some overwinter.
Green heron (Butorides virescens)	Common; nesting in area.
Common egret (Casmerodius albus)	Some nest in Great Lakes area.
Cattle egret (Ardeola ibis)	Found in upland environs; nest in this area.
Snowy egret (Egretta thula)	Some may be found nesting in this area; rare.
Black-crowned night heron (Nycticorax nyctiocorax)	Nest in Great Lakes area especially in southern region.
Least bittern (Ixobrychus exilis)	Nest in area in dense aquatic vegetation.
Americsan bittern (Botaurus lentiginosus)	Found in freshwater swamps. Some may overwinter in the area.
King rail (Rallus elegans)	Nest in the area; in marshes just off water.
Virginia rail (Rallus limicola)	High density of nesting birds found in Great Lakes region.
Sora rail (Porzana carolina)	Nest in area in marsh vegetation , close water surface.
Yellow rail(Coturnicops noveboracensis)	Nest in western Lake Erie and Lake St. Clair; migrates through the area.
Black rail (Laterallus jamaicensis)	Nest on Lower Lakes.

Shorebirds

Species	Remarks
Common snipe (Capella gallinago)	Common; nest in and migrate through the area.
Golden plovesr (Pluvialis dominica)	Mainly upland.
Black-bellied plover (Pluvialis squatarola)	Mainly along ocean but occasionally found along Great Lakes in migration.
Semipalmated plover (Charadrius semipalmatus)	Can be found on muddy shores in Autumn especially in dry years.
Piping plover (Charadrius melodus)	Nests and feeds on sandy shores.
Hudsonian godwit (Limosa haemastica)	Occasionally found inland during migration.
Marbled godwit (Limosa fedoa)	Nests in prairies west of Great Lakes area but rarely seen during migration inland from the ocean.

Whimbrel (Numenius phaeopus)	From Europe; some migrants may be seen in the area but mainly found on salt water.
Long-billed curlew (Numenius americanus)	Rare inland.
Upland sandpiper (Bartramia longicauda)	A more upland species, nests in dry grassland. Not often found near water.
Greater yellowlegs (Tringa melanoleuca)	Common along lakes and streams, feeds on minnows and other animal life.
Lesser yellowlegs (Tringa flavipes)	Not as common as Greater yellowlegs but still found along the lakes and streams.
Solitary sandpiper (Tringa solitaria)	Breeds farther north; migrates through and may be common in Fall or Spring, feeds on mud flats.
Spooted sandpiper (Actitis macularia)	Nests near shore and feeds along waters edge on small animals.
Ruddy turnstone (Arenaria interpres)	Rare inland from sea.
Shortbilled dowitche. (Limnodromus griseus)	Very rare inland.
Longbilled dowitcher (Limnodromus scolopaceus)	Rarely found inland.
Red knot (Calidris canutus)	Rare inland from ocean.
Sanderling (Calidris alba)	Rare inland.
Semipalmated sandpiper (Calidris pusilla)	Regularly found inland during migration, usually found on sandy areas.
Western sandpiper (Calidris mauri)	Very rare inland from the ocean.
Least sandpiper (Calidris minutilla)	Found along the marshy edges of Lakes during Fall and Spring.
White-rumped sandpiper (Calidris fuscicollis)	Rarely found inland.
Bairds sandpiper (Caidris melanotos)	Feeds generally in meadows away from the shore.
Dunlin (Calidris alpina)	Rarely found inland from the ocean.
Stilt sandpiper (Micropalama himantopus)	Favors shallow pools with mud bottoms and patches of grass, casual inland from the sea.
Buff breasted sandpiper (Tryngites subruficollis)	Rare east of Mississippi.
Ruff (Philomachus pugnax)	Rarely found inland.
Red phalarope (Phalaropus fulicarius)	Uncommon to area, may be seen during migration.
Northern phalarope (Phalaropus lobatus)	Very rare inland from the ocean.
American avocet (Recurvirostra americana)	Rare east of Mississippi.

Gulls and Terns of the Great Lakes Region

Species	Remarks
Glaucous gull (Larus hyperboreus)	Some overwinter along St. Lawrence River and Lake Ontario and perhaps the other lakes.
Iceland gull (Larus glaucoides)	Same as glaucous gull.
Great blackbacked gull (Larus marinus)	Winters along Great Lakes to some extent but not common.
Herring gull (Larus argentatus)	Most common gull, nests on ground or in trees.
Ring-billed gull (Larus delawarensis)	Nests in marshes on ground Lake Ontario. Winters throughout area.
Franklins gull(Larus pipixcan)	Some migrate through Great Lakes.
Bonoparts gull (Laus philadelphia)	Migrants seen on Great Lakes, some overwinter there on Lake Erie and Lake Ontario.
Little gull (Larus minutus)	Breeds in Europe (pssibly in S.E. Ontario); winter along eastern Great Lakes.
Forsters tern (Sterna forsteri)	Breeds along N.W. Great Lakes in marshes.
Common tern (Sterna hirundo)	Nests in sand or grass along shores.
Least tern (Stena albifrons)	May find a few breeding near Great Lakes area but rare.
Black tern (Chlidonius niger)	Nests on dead reeds in marshes, feeds on insects usually.
Caspian tern (CSaspia hydroprogne)	Nests are on sand.

Other Birds of the Great Lakes Region

Species	Remarks
Sandhill crane (Grus canadensis)	Not restricted to wetlands, but generally nests in marshes on ground.
Bald eagle (Haliaeetus leucocephalus)	Very few nesting birds along Great Lakes, feeds mainly on fish, some may winter in this area.
Marsh hawk (Circs cyaneus)	Nests usually in marshes close to ground.
Osprey (Pandion haliaetus)	Rare - nests in trees or on ground, food is almost exclusively fish.

Belted kingfisher (Megaceryle alcyon)	Nests are burrows in riverbanks or sandbanks, feeds on fish, crayfish, insects and small rodents, some may winter along Great Lakes
Bank swallow (Riparia riparia)	Nests in burrows in banks generally along rivers or lakes. Abundance depends on suitable nesting sites.
Tree swallow (Iridoprocne bicolor)	Nests many diverse sites, but prefers to be near water.
Rough-winged swallow (Stelgidopteryx ruficollis)	Nests in banks (like bank swallow) prefers areas near water.
Carolina wren (Thryothorus ludovicianus)	Nests preferably near streams or lakes. Winters in area.
Long-billed marsh wren (Telmatodytes palustris)	Nests built in cattails or rushes 1-3' above water. Feeds on insects.
Short-billed marsh wren (Cistothorus plantensis)	Nests in grass or sedge marsh close to water surface. Food: insects and spiders.
Prothonotary warbler (Protonotaria citrea)	Lives in wooded swamps or periodical flooded woodlands. Food is insects.
Northern waterthrush (Seiurus noveboracensis)	Nests in swampy woodlands near streams or lakes, near ground. Feeds on aquatic insects, worms and invertebrates.
Louisiana waterthrush (Seiurus motacilla)	Nests in wooded areas along streams and rivers. Food: insects, spiders and invertebrates.
Yellowthroat (Geothlypis trichas)	Prefers marshes and swamps and wet brushlands. Nests built close to ground in reeds, grasses or brush. Food: insects.
Wilsons warbler (Wilsonia pusilla)	Nests along streams and marshes in northern part of Great Lakes area. Feeds on insects caught in air or water.

Bobolink (<u>Dolichonyx oryzivorus</u>)	Nests in open fields but during migration found usually in marshes. Food: grain especially, rice in Fall and Spring.
Yellow-headed blackbird (<u>Xanthocephalus xanthocephalus</u>)	Nests in colonies in reeds 6-3' above water 2-4' deep.
Red-winged blackbird (<u>Agelaius phoeniceus</u>)	Prefers to nest in cattails and rushes on marshes. Feeds a lot on grains and agricultural crops.
Rusty blackbird (<u>Euphagus carolinus</u>)	Nests in wooded marshes 2-25' above water. Food: insects and seeds.
Sharptailed sparrow (<u>Ammospiza caudacuta</u>)	Found during migration along margins of marshes. Food: insects, spiders, snails and small invertebrates.
Water pipit (<u>Anthus spinoletta</u>)	Migrates through. Found in grasslands or open beaches. Food: mollusks, crustaceans, seeds and insects.
Swamp sparrow (<u>Melospiza georgiana</u>)	Nests in brush or grasses along marshes. Food: insects and seeds.

Many other bird species not included in this list which are not associated with water oriented habitats may be observed in the Great Lakes area, especially during migration.

All species listed are obviously not found in all sections of the Great Lakes system. Scientific names taken from Peterson (1956), Bellrose (1976) and Sanderson ed (1977); other information from these sources and also Martin et al. (1951), Robbins et al. (1966), Peterson (1956), Bull (1964) and Pearson et al. (1963).
and seeds.

<u>Reptiles and Amphibians</u>

<u>Species</u>	<u>Remarks</u>
Snapping turtle (<u>Chelydra serpentina</u>)	Common in any body of water.
Stinkpot (<u>Sternotherus odoratus</u>)	
Spotted turtle (<u>Clemmys guttata</u>)	Marshy meadows, bogs, and swamps.
Bog turtle (<u>Clemmys muhlenbergi</u>)	Rare; prefers bogs, swamps or slow moving streams.

Eastern box turtle (Terrapene carolina)	Mainly terrestrial.
Map turtle (Graptemys geographica)	Prefers large bodies of water.
Red-eared turtle (Chrysemys scripta)	A few isolated colonies aong Lakes Erie and St. Clair. Rare.
Painted turtle (Chrysemys picta)	
Blandings turtle (Emydoidea blandingi)	
Eastern spiny softshell turtle (Trionys spiniferus)	Mainly in rivers.
Northern water snake (Natrix spiedon)	Common in most wet areas.
Lake Erie water snake (Natrix sipedon)	A subspecies restricted to the Islands of Put-in-Bay Archipelago Lake Erie.
Queen snake (Natrix septemvittata)	
Kirtlands water snake (Natrix kirtlandi)	In the Great Lakes area found along west Lake Erie and Lake St. Clair and south Lake Michigan.
Northern brown snake (Storeria dekayi)	Found in cities or bogs, swamps and freshwater marshes.
Garter snake (Thamnophis sp.)	Occur almost anywhere. There are five species occurring in the area.
Northern ribbon snake (Thamnophis sauritus)	Semiaquatic snake found around ponds, bogs, streams, and swamps.
Fox snake (Elaphe vulpina)	Restricted to the marshes around Lake Erie, St. Clair and Huron.
Eastern milk snake (Lampropeltis triangulum)	Found in many habitats, usually terrestrial.
Massasauga (Sistrurus catenatus)	Prefers bogs and swamps.
Mudpuppy (Necturus maculosus)	Gilled; restricted to permanent water bodies.
Small-mouthed salamander (Ambystroma texanum)	Restricted in this area to western Lake Erie and Pelee Island.
Easter tiger salamander (Ambystoma tigrinum)	Lake St. Clair and western Lake Erie.
Red-spotted newt (Notophthalmus viridescens)	Common
Dusky salamander (Desmognathus sp.)	Two species occur in this area.
Slimy salamander (Plethodon glutinosus)	Along Lakes Erie and Ontario in the United States.
Four toed salamander (Hemidactylium scutatum)	Usually associated with sphagnum.
American toad (Bufo americanus)	Common everywhere.
Fowlers toad (Bufo woodhousei)	
Cricket toad (Acris crepitans)	Western Lakes Erie, St. Clair, Huron and Michigan.

Spring peeper (Hyla crucifer)	Usually in woodlands or shrubs.
Gray tree frog (Hyla versicolor)	
Chorus frog (Pseudacris triseriata)	Along shallow bodies of water during breeding; otherwise, anywhere.
Bullfrog (Rana catesbeiana)	Common; always near water.
Green frog (Rana clamitans)	Common; near shallow fresh water.
Wood frog (Rana sylvatica)	Usually found in wooded areas.
Mink frog (Rana septentrionalis)	Northern species found along Lakes Superior, Huron, Ontario and St. Lawrence River.
Leopard frog (Rana pipiens)	Common.
Pickerel frog (Rana palustris)	Typically in cool clear water.

Information taken from Conant (1975).

Mammals of the Great Lakes Region. This is a list of all mammals found in this area. The asterisks next to the animals's name indicates their association with wetland habitat. One star means the animal is often found in the vicinity of marshes, however, it can get along without them quite well. Two stars indicate the animal prefers marshy areas. Three stars indicate a strong reliance on wetlands for survival. No star indicates little or no association with wetlands.

Species	Remarks
Opossum (Didelphis marsupialis)**	Feeds on anything, but fairly confined to wooded areas around streams, lakes and in swamps.
Eastern mole (Scalopus aquaticus)	Found in more agricultural areas. Feeds on worms and insects.
Hairy-tail mole (Parascalops breweri)	Not likely to be found in wet soils.
Starnose mole (Condylura cristata)***	Spends some time in water. Feeds on aquatic worms and insects.
Masked shrew (Sorex cinereus)*	Inhabits grassy areas near water. Food is mainly insects.
Smoky shrew (Sorex fumeus)	Confined to forests.
Artic shrew (Sorex arcticus)**	Found in tamarack and spruce swamps.
Longtail shrew (Sorex dispar)*	Prefers moist conditions in coniferous forests.
Northern water shrew (Soex palustris)***	Feet adapted for swimming. Lives along streams and swamps.

Pigmy shrew (Microsorex hoyi)*	Found in both wet and dry stuations in wooded areas.
Least shrew (Cryptotis parva)	Open grasses and brush.
Shortail shrew (Blarina brevicauda)	Found in any habitat.
Little brown myotis (Myotis lucifugus)*	May be found feeding over lakes and rivers. Eats insects.
Indiana bat (Myotis sodalis)***	Rare. Little known about their habits. May require reparian habitat in summer.
Keen myotis (Myotis keeni)	Found in forested areas.
Small footed myotis (Myotis subulatus)	Mountainous areas.
Silvser-haired bat (Lasinoycteris noctivagans)*	Forested areas along streams or lakes, often feed over water.
Eastern pipistrel (Pipistrellus subflavus)	Forested areas.
Big brown bat (Eptesicus fuscus)	Found anywhere.
Evening bat (Nycticeius humeralis)	Wooded areas.
Red bat (Lasiurus borealis)	Wooded areas.
Hoary bat (Lasiurus cinereus)	Forested areas.
Black bear (Ursus americanus)*	Heavily forested areas and dense swamps.
Raccoon (Procyon lotor)**	Prefers to be around streams and lakes but spends a lot of time in agricultural areas.
Marten (Martes americana)	Restricted to dense coniferous forests.
Fisher (Martes pennanti)*	Found in forests, usually near water.
Shortail weasel (Mustela erminea)	Found in woodlands.
Least weasel(Mustela rixosa)	Meadows, fields and maybe woodlands.
Longtail weasel (Mustela frenata)**	Forests, brushland and prairies, especially near water.
Mink (Mustela vison)**	Wooded areas especially along streams and lakes. Feeds on mammals, birds, eggs, frogs and fish.
River otter (Lutra canadensis)***	Lives along streams and lakes, eats primarily fish.
Badger (Taxidea taxus)	Open grassland.
Striped skunk (Mephitis mephitis)*	Usually found in woods, brush or meadows but generally not more than two miles from water.
Red fox (Vulpes fulva)	Found anywhere.
Grey fox (Urocyon cinereoargenteus)	Forests and open brush land.
Coyote (Canis latrans)	Open or semi-open country.
Wolf (Canis lupus)	Prefers forested areas.

Lynx (Lynx canadensis)	Confined to primitive forests. Rare in U.S.
Bobcat (Lyunx rufus)	Swamps and broken country with adequate brush cover.
Woodchuk (Marmota monax)	Forests and fields.
Thirteen lined ground squirrel (Citellus tridecemlineatus)	Open grasslands and golf course.
Franklin ground squirrel (Citellus franklini)	Open prairies or edges of woodlands.
Least chipmunk (Eutamias minimus)	Cedar, spruce and hemlock forests.
Eastern chipmunk (Tamias striatus)	Woodlands and brushland.
Red squirrel (Tamiasciurus hudsonicus)	Coniferous and hardwood forests.
Eastern grey squirrel (Sciurus carolinensis)	Hardwood forests.
Eastern fox squirrel (Sciurus niger)	Small areas of hardwoods within agricultural areas.
Southern flying squirrel (Glaucomys volans)	Wooded areas.
Northern flying squirrel (Glaucomys sabrinus)	Wooded areas.
Beaver (Castor canadensis)***	Wooded streams and lake shores.
Deer mouse (Peromyscus maniculatus)	Found anywhere.
White-footed mouse (Peromyscus leucopus)	Found anywhere.
Southern bog lemming (Synaptomys cooperi)***	Found in damp bogs or meadows, local areas.
Heather vole (Phenacomys intermedius)	Northern species but restricted to dry areas.
Boreal red-backed vole (Clethrionomys gapperi)*	Hardwood forests or coniferous swamps.
Meadow vole (Microtus pennsylvanicus)	Moist low areas and grasslands.
Yellownose vole (Microtus chrotorrhinus)	Rocky areas.
Prairie vole (Pedomys ochrogaster)	Open grassland and cultivated fields.
Pine vole (Pitymys pinetorum)	Deciduous forests and brushy areas.
Muskrat (Ondatra zibethica)***	Marshes, ponds, lakes, streams, especially where there are heavy cattails and rushes.
Norway rat (Rattus norvegicus)	Found around human habitation.
House mouse (Mus musculus)	Same as Norway rat.
Meadow jumping mouse (Zapus hudsonius)	Found anywhere, prefers meadows.
Woodland jumping mouse (Napaeozapus insignis)*	Lives in forests near streams and lakes.
Porcupine (Erethizon dorsatum)	Confined to forested areas.
Snowshoe hare (Lepus americanus)	Spruce and cedar swamps and woodlands.
Eastern Cottontail (Sylvilagus floridanus)	Brushy areas and edges of swamps.

Whitetail deer (<u>Ococoileus virginianus</u>)	Found anywhere but prefers woodland borders.
Moose (<u>Alces alces</u>)**	Forested regions - but utilizes swamps and lakes for food in summer months.

Scientific names and other information for mammals taken from Burt (1957).

ANNEX 5

Changes in Yearly Water Levels with Regulation Plans

The following bar graphs depict the historical water levels as they deviate from the long-term BOC mean water level for Lakes St. Clair, Erie and Ontario. The levels are considered in 6" intervals beginning at levels greater than 3" from the BOC mean (for simplicity these levels are considered in whole inches rather than fractions of an inch). The center line shows levels within 3" of the BOC mean; above this line are higher than the BOC mean level; below the line are lower than the BOC mean level. An interpretation of some of the important water level changes can be found on the corresponding Tables.

Occurrence and duration of given water levels as compared to B.O.C. mean
Lake Erie Plan 77

	BOC	Plan 6L	Plan 15S2	Plan 25N3
No. of years with levels within 3" of BOC mean	17	21	20	18
No. of years with levels 3" below BOC mean	30	32	37	53
No. of years with levels 9" below BOC mean	13	17	21	31
No. of years with levels 15" below BOC mean	7	7	7	14
No. of years with levels 21" below BOC mean	2	2	2	4
No. of years with levels 3" above BOC mean	30	24	20	6
No. of years with levels 9" above BOC mean	14	9	7	4
No. of years with levels 15" above BOC mean	6	4	4	0
No. of years with levels 21" above BOC mean	3	2	0	0
*Duration of low levels				
3-5 years	1	0	1	0
6-8 years	1	1	0	1
9-11 years	0	1	1	0
12 years	0	0	0	0
**Duration of high levels				
3-5 years	0	1	1	1
6-8 years	1	1	1	1
9-11 years	0	0	0	0
12 years	0	0	0	0

* The duration of low levels is calculated as consecutive years with levels more than 9" below the BOC mean or where several years of low levels are interrupted by low levels not exceeding 1 year out of 4 or 2 consecutive years. The values under each plan refer to the number of times the low or high periods occurred.

** The duration of high levels is calculated as consecutive years with levels more than 9" above the BOC mean or where several years of high levels are interrupted by lower levels not exceeding 1 year out of 4 or 2 consecutive years. The values under each plan refer to the number of times the low or high periods occurred.

Occurrence and duration of given water levels as compared to B.O.C. mean.
Lake St. Clair Plan 77

	BOC	Plan 6L	Plan 15S2	Plan 25N3
No. of years with levels within 3" of BOC mean	14	18	20	32
No. of years with levels 3" below BOC mean	31	31	32	43
No. of years with levels 9" below BOC mean	17	18	20	24
No. of years with levels 15" below BOC mean	8	8	8	10
No. of years with levels 21" below BOC mean	2	2	2	4
No. of years with levels 3" above BOC mean	32	28	25	13
No. of years with levels 9" above BOC mean	14	12	9	6
No. of years with levels 15" above BOC mean	7	6	6	2
No. of years with levels 21" above BOC mean	3	2	2	0
*Duration of low levels				
3-5 years	0	1	1	1
6-8 years	1	1	0	0
9-11 years	1	1	1	1
12 years	0	0	0	0
**Duration of high levels				
3-5 years	1	1	0	1
6-8 years	1	1	1	0
9-11 years	0	0	0	0
12 years	0	0	0	0

* The duration of low levels is calculated as consecutive years with levels more than 9" below the BOC mean or where several years of high levels are interrupted by higher levels not exceeding 1 year out of 4 or 2 consecutive years. The values under each plan refer to the number of times the period occurred.

** The duration of high levels is calculated as consecutive years with levels more than 9" above the BOC mean or where several years of high levels are interrupted by lower levels not exceeding 1 year out of 4 or 2 consecutive years. The values under each plan refer to the number of times the period occurred.

Occurrence and duration of given water levels as compared to B.O..C. mean.
Lake Ontario Plan 77 - Category 2

	BOC	Plan 6L	Plan 15S2	Plan 25N3
No. of years with levels within 3" of BOC mean	42	48	43	40
No. of years with levels 3" below BOC mean	16	9	10	13
No. of years with levels 9" below BOC mean	4	1	1	1
No. of years with levels 15" below BOC mean	1	0	0	0
No. of years with levels 21" below BOC mean	0	0	0	0
No. of years with levels 3" above BOC mean	19	20	24	24
No. of years with levels 9" above BOC mean	1	3	3	3
No. of years with levels 15" above BOC mean	0	1	1	1
No. of years with levels 21" above BOC mean	0	0	0	0
*Duration of low levels				
3-5 years	0	0	0	0
6-8 years	0	0	0	0
9-11 years	0	0	0	0
12 years	0	0	0	0
**Duration of high levels				
3-5 years	0	1	1	1
6-8 years	0	0	0	0
9-11 years	0	0	0	0
12 years	0	0	0	0

* The duration of low levels is calculated as consecutive years with levels more than 9" below the BOC mean or where several years of low levels are interrupted by higher levels not exceeding 1 year out of 4 or 2 consecutive years. The values under each plan refer to the number of times the low periods occurred.

** The duration of high levels is calculated as consecutive years with levels more than 9" above the BOC mean or where several years of low levels are interrupted by lower levels not exceeding 1 year out of 4 or 2 consecutive years. The values under each plan refer to the number of times the low periods occurred.

Occurrence and duration of given water levels as compared to B.O.C. mean.
Lake Ontario Plan 77 - Category 3

	BOC	Plan 6L	Plan 15S2	Plan 25N3
No. of years with levels within 3" of BOC mean	43	46	43	43
No. of years with levels 3" below BOC mean	15	12	14	11
No. of years with levels 9" below BOC mean	4	3	3	1
No. of years with levels 15" below BOC mean	1	0	0	0
No. of years with levels 21" below BOC mean	0	0	0	0
No. of years with levels 3" above BOC mean	19	19	20	23
No. of years with levels 9" above BOC mean	1	1	1	1
No. of years with levels 15" above BOC mean	0	0	0	0
No. of years with levels 21" above BOC mean	0	0	0	0
*Duration of low levels				
3-5 years	0	0	0	0
6-8 years	0	0	0	0
9-11 years	0	0	0	0
12 years	0	0	0	0
**Duration of high levels				
3-5 years	0	0	0	0
6-8 years	0	0	0	0
9-11 years	0	0	0	0
12 years	0	0	0	0

* The duration of low levels is calculated as consecutive years with levels more than 9" below the BOC mean or where several years of low levels are interrupted by higher levels not exceeding 1 year out of 4 or 2 consecutive years. The values under each plan refer to the number of times the low periods occurred.
** The duration of high levels is calculated as consecutive years with levels more than 9" above the BOC mean or where several years of low levels are interrupted by lower levels not exceeding 1 year out of 4 or 2 consecutive years. The values under each plan refer to the number of times the low periods occurred.

ANNEX 6

Occurrence of Water Levels for Lake St. Clair - Plan 77

Lake Level	BOC No.	BOC Cum.#	BOC Cum.%	25N3 No.	25N3 Cum.#	25N3 Cum.%	15S2 No.	15S2 Cum.#	15S2 Cum.%	6L No.	6L Cum.#	6L Cum.%
571.2-571.29	0	0	0	0	0	0	1	1	1	0	0	0
571.3-571.39	0	0	0	0	0	0	0	1	1	0	0	0
571.4-571.49	0	0	0	1	1	1	0	1	1	0	0	0
571.5-571.59	1	1	1	0	1	1	1	2	3	1	1	1
571.6-571.69	0	1	1	0	1	1	0	2	3	0	1	1
571.7-571.79	0	1	1	1	2	3	2	4	5	1	2	3
571.8-571.89	1	2	3	4	6	8	1	5	6	0	2	3
571.9-571.99	3	5	6	1	7	9	2	7	9	3	5	6
572.0-572.09	2	7	9	1	8	10	0	7	9	2	7	9
571.1-572.19	1	8	10	0	8	10	1	8	10	1	8	10
572.2-572.29	0	8	10	2	10	13	0	8	10	0	8	10
572.3-572.39	0	8	10	1	11	14	2	10	13	0	8	10
572.4-572.49	1	9	12	3	14	18	3	13	17	2	10	13
572.5-572.59	1	10	13	4	18	23	1	14	18	1	11	14
572.6-571.69	3	13	17	4	22	29	3	17	22	3	14	18
572.7-571.79	4	17	22	2	24	31	3	20	26	4	18	23
571.8-572.89	2	19	25	3	27	35	1	21	27	2	20	26
572.9-572.99	3	22	29	3	30	39	5	26	34	2	22	29
573.0-573.09	2	24	31	4	34	44	1	27	35	5	27	35
573.1-573.19	3	27	35	4	38	49	4	31	40	1	28	36
573.2-573.29	4	31	40	2	40	52	2	33	43	3	31	40
573.3-573.39	0	31	40	7	47	61	3	36	47	1	32	42
573.4-573.49	2	33	43	6	53	69	2	38	49	2	34	44
573.5-573.59	3	36	47	2	55	71	5	43	56	6	40	52
573.6-573.69	5	41	53	4	59	77	4	47	61	3	43	56
573.7-573.79	3	44	57	4	63	82	2	49	64	4	47	61
573.8-573.89	4	48	62	3	66	86	4	53	69	4	51	67
573.9-573.99	4	52	68	2	68	88	2	55	71	3	54	70
574.0-574.09	2	54	70	2	70	91	5	60	78	2	56	73
574.1-574.19	2	56	73	1	71	92	2	62	81	6	62	81
574.2-574.29	6	62	81	0	71	92	3	65	84	2	64	83
574.3-574.39	2	64	83	0	71	92	2	67	87	2	66	86
574.4-574.49	2	66	86	0	71	92	0	67	87	2	68	88
574.5-574.59	2	68	88	2	73	95	3	70	91	1	69	90
574.6-574.69	1	69	90	2	75	97	0	70	91	1	70	91
574.7-574.79	1	70	91	0	75	97	1	71	92	1	71	92
574.8-574.89	0	70	91	0	75	97	0	71	92	0	71	92
574.9-574.99	1	71	92	1	76	99	0	71	92	0	71	92
575.0-575.09	0	72	92	1	77	100	2	73	95	0	71	92
575.1-575.19	0	71	92					74	96	3	74	96
575.2-575.29	3	74	96				1	75	97	0	74	96
575.3-575.39	0	74	96				0	75	97	1	75	97
575.4-575.49	1	75	97				0	75	97	0	75	97
575.5-575.59	0	75	97				1	76	99	1	76	99
575.6-575.69	0	75	97				1	77	100	1	77	100
575.7-575.79	2	77	100									
575.8-575.89												
575.9-575.99												
Mean		573.59			573.17			573.43			573.52	
Range (approx)		4.1			3.6			4.4			4.14	

Occurrence of water levels for Lake Erie - Plan 77.

	BOC			25N3			15S2			6L		
Lake Level	No.	Cum.#	Cum.%	No.	Cum.#	Cum.%	No.	Cum.#	Cum.%	No.	Cum.#	Cum.%
568.6-568.69	0	0	0	0	0	0	0	0	0	0	0	0
568.7-568.79	0	0	0	0	0	0	0	0	0	0	0	0
568.8-568.89	0	0	0	4	4	5	1	1	1	0	0	0
568.9-568.99	2	2	3	0	4	5	1	2	3	2	2	3
569.0-569.09	1	3	4	0	4	5	2	4	5	2	4	5
569.1-569.19	1	4	5	3	7	9	0	9	5	0	4	5
569.2-569.29	0	4	5	2	9	12	2	6	8	1	5	6
569.3-569.39	2	6	7	1	10	13	0	6	8	1	6	8
569.4-569.49	1	7	9	3	13	17	1	7	9	1	7	9
569.5-569.59	1	8	10	1	14	18	1	8	10	1	8	10
569.6-569.69	0	8	10	2	16	21	2	10	13	1	9	12
569.7-569.79	1	9	11	2	18	23	1	11	14	1	10	13
569.8-569.89	0	9	11	5	23	30	4	15	20	1	11	14
569.9-569.99	4	13	17	8	31	40	5	20	26	3	14	18
570.0-570.09	5	18	24	6	37	48	2	22	29	6	20	26
570.1-570.19	2	20	26	1	38	49	3	25	32	5	25	32
570.2-570.29	5	25	32	6	44	57	2	27	35	1	26	34
570.3-570.39	1	26	34	4	48	62	5	32	42	2	28	36
570.4-570.49	4	30	39	5	53	69	4	36	46	3	31	40
570.5-570.59	1	31	40	7	60	78	5	41	53	2	33	43
570.6-570.69	3	34	44	4	64	83	4	45	58	6	39	51
570.7-570.79	3	37	48	3	67	87	4	49	64	4	43	56
570.8-570.89	4	41	53	1	68	88	4	53	69	4	47	61
570.9-570.99	5	46	60	3	71	92	31	56	73	6	53	69
571.0-571.09	7	53	69	1	72	94	3	59	77	2	55	71
571.1-571-19	1	54	70	1	73	95	6	65	84	2	57	74
571.2-571.29	4	58	75	0	73	95	3	68	88	5	62	81
571.3-571.39	3	61	79	0	73	95	1	69	89	4	66	86
571.4-571.49	2	63	82	0	73	95	1	70	91	2	68	88
571.5-571.59	4	67	87	1	74	96	1	71	92	1	69	90
571.6-571.69	1	68	88	2	76	99	1	72	94	1	70	91
571.7-571.79	2	70	91	1	77	100	1	73	95	0	70	91
571.8-571.89	0	70	70				0	73	95	2	72	94
571.9-571.99	1	71	92				0	73	95	0	71	94
572.0-572.09	1	72	94				0	73	95	1	73	95
572.1-571.19	1	73	95				1	75	97	0	73	95
572.2-572.29	0	73	95				0	75	97	1	74	96
572.3-572.39	0	73	95				1	76	99	1	75	97
572.4-572.49	1	79	96				1	77	100	0	75	97
572.5-572.59	1	75	97							1	76	99
572.6-572.69	0	75	97							1	77	100
572.7-572.79	1	76	99									
572.8-572.89	1	77	100									
572.9-572.99												
Mean		570.76			570.17			570.53			570.66	
Range (approx)		3.9			2.9			3.5			3.7	

Occurrence of water levels for Lake Ontario 1- Plan 77 - Category 2

	BOC			25N3			15S2			6L		
Lake Level	No.	Cum.#	Cum.%	No.	Cum.#	Cum.%	No.	Cum.#	Cum.%	No.	Cum.#	Cum.%
243.19	1	1	1	0	0	0	0	0	0	0	0	0
243.2-243.29	0	1	1	0	0	0	0	0	0	1	1	1
243.3-243.39	0	1	1	0	0	0	1	1	1	0	1	1
243.4-243.49	0	1	1	1	1	1	0	0	1	0	1	1
243.5-243.59	0	1	1	0	1	1	0	1	1	0	1	1
243.6-243.69	2	3	4	0	1	1	0	1	1	0	1	1
243.7-243.79	0	3	4	0	1	1	0	1	1	0	1	1
243.8-243.89	1	4	5	0	1	1	0	1	1	0	1	1
243.9-243.99	1	5	7	1	2	3	1	2	3	1	2	3
244.0-244.09	2	7	9	1	3	4	3	5	7	2	4	5
244.1-244.19	3	10	13	1	4	5	1	6	8	1	5	7
244.2-244.29	1	11	14	4	8	10	2	8	10	1	6	8
244.3-244.39	7	18	23	7	15	19	6	14	18	6	12	16
244.4-244.49	9	27	35	7	22	29	6	20	26	9	21	27
244.5-244.59	0	36	47	9	31	40	12	32	42	15	36	47
244.6-244.69	7	43	56	5	36	47	9	41	53	7	43	57
244.7-244.79	14	57	74	9	45	58	6	47	61	9	52	68
244.8-244.89	3	60	78	8	53	69	9	56	73	9	61	79
244.9-244.99	5	65	84	4	57	74	5	61	79	5	66	86
245.0-245.09	2	67	87	6	63	82	9	70	91	3	69	90
245.1-245.19	6	73	95	7	70	91	4	74	96	4	73	95
245.2-245.29	2	75	97	2	72	94	0	74	96	1	74	96
245.3-245.39	1	76	99	1	73	95	0	74	96	0	74	96
245.4-245.49	0	76	99	0	73	95	0	74	96	0	74	96
245.5-245.59	0	76	99	1	74	96	0	74	96	0	74	96
245.6-245.69	1	77	100	0	74	96	1	75	97	1	75	97
245.7-245.79				2	76	99	1	76	99	1	76	99
245.8-245.89				0	76	99	0	76	99	0	76	99
245.9-245.99				0	76	99	0	76	99	1	77	100
246.0-246.09				1	77	100	1	77	100	0	77	100
Mean		244.61			244.71			244.69			244.66	
Range		2.55			2.6			2.64			2.71	

ANNEX 7

COMMERCIAL FISHERY STATISTICS FOR
LAKE ST. CLAIR, LAKE ERIE AND THE NIAGARA RIVER

Michigan creel census estimates of total sport fishing effort and catch for Lake St. Clair and connecting waters.

Year	Number Angler Days (x1000)	Catch All Species (x1000)	Catch Of All Species Per Angler Day
1942[1,4]	294.5	788.6	3.97
1943[1,5]	342.8	606.6	2.30
1966[1,2,6]	752.0	2931.4	3.90
1967[1,6]	1911.6	7217.3	3.78
1971[3,7]	1020.4	6720.2	6.59
1972[3,7]	1202.4	6200.0	4.90
1973[3,7]	1396.2	10,040.4	6.23
1974[3,7]	1320.9	7664.7	5.80
1975[3,7]	2090.8	11,125.5	5.32
1976[3,7]	1556.5	7243.4	4.65
1977[3,7]	1905.3	9673.0	5.08

[1]Does not include winter fishery.

[2]Does not include fishing activity on St. Clair and Detroit Rivers.

[3]Mail survey estimates which include the winter fishery and the St. Clair and Detroit Rivers.

[4]Krumholtz, L. A., and W. F. Carbine, 1943. Results of the cooperative creel census on the connecting water between Lake Huron and Lake Erie in 1942. Mich. Dept. Conserv. Fish. Res. Rep. 879. 24 pp.

[5]Krumholtz, L. A., and W. F. Carbine, 1945. Results of the cooperative creel census on the connecting waters between Lake Huron and Lake Erie, 1943. Mich. Dept. Conserv. Fish. Res. Rep. 997. 24 pp.

[6]Estimates from Michigan Dept. Natural Resources creek survey--data published.

[7]Jamsen, G. C. (1971 through 1977). Michigan's (year) sport fishery. Mich Dep. Nat. Resour. Surv. Stat. Serv. Rep. No. 116 through No. 167.

Commercial fish production and value in the combined U.S. and Canadian water of Lake Erie, 1978 (Preliminary figures--not for official publication, Report to Great Lakes Fisheries Commission 1979)

Species	1978	
	Pounds x1,000	$Value x1,000
Rainbow smelt	24,234	1,959
Yellow perch	10,832	7,163
White bass	3,502	1,978
Carp	1,918	122
Gizzard shad	1,558	23
Freshwater drum	1,525	55
Goldfish	757	33
Walleye	650	595
Channel Catfish	326	157
Bullhead	118	20
Quillback	103	6
Suckers	72	7
Buffalo	56	18
Sunfish	50	24
Bowfin	27	2
Rock bass	21	10
Lake whitefish	5	3
Other species	1,[illegible]53	47
Total	47,507	12,222

Summary of Upper Niagara bait-fish harvest and value 1973-1976 (from Buckingham et al. 1977)

Year	Total Harvest (doz)	Wholesale (doz)	Wholesale Value	Retail (doz)	Retail Value	Preserved (doz)	Preserved Value	Industry Total Value
1976	8,456,925	7,333,136	$347,397	52,169	$12,545	1,088,000	$4,790	$364,732
1975	5,836,692	3,961,558	$ 29,120	68,743	$16,717	1,248,474	$9,627	$ 55,464
1974	11,905,419	11,144,112	$ 82,860	292,876	$59,562	1,579,660	$2,105	$144,547
1973	13,444,933	13,546,953	$551,459	61,932	$ 7,792	20,788	$ 372	$559,633

ANNEX 8

FAMILIES AND SPECIES RECORDED FROM NIAGARA RIVER AND ITS TRIBUTARIES AND LAKE ONTARIO

Families of fishes recorded from the Niagara River and tributaries (from data supplied by the OMNR Niagara District Office)

Family	No. of Genera	No. of Species
Petromyzontidae (lampreys)	3	3
Acipenseridae (sturgeons)	1	1
Lepisosteidae (gars)	1	2
Amiidae (bowfins)	1	1
Clupeidae (herrings)	2	3
Salmonidae (trouts, whitefishes)	5	8
Osmeridae (smelts)	1	1
Hiodontidae (mooneyes)	1	1
Umbridae (mudminnows)	1	1
Esocidae (pikes)	1	3
Cyprinidae (minnows)	12	25
Catostomidae (suckers)	5	7
Ictaluridae (catfishes)	2	6
Anguillidae (eels)	1	1
Cyprinodontidae (killifishes)	1	1
Gadidae (cod fishes)	1	1
Gasterosteidae (sticklebacks)	2	2
Percopsidae (troutperches)	1	1
Serranidae (sea basses)	1	2
Centrarchidae (sunfishes)	4	7
Percidae (perches)	4	10
Sciaenidae (drums)	1	1
Cottidae (sculpins)	2	2
Atherinidae (silversides)	1	1
TOTAL	55	91

Species Recorded in Niagara River

Source	Scientific Name	Common Name
(2)	Ichthyomyzon unicuspis	siver lamprey
(2)	Lampetra lamottei	brook lamprey
(2)	Petromyzon marinus	sea lamprey
(2) (4)	Acipenses fulvescens	lake sturgeon
(2)	Lepisosteus oculatus	spotted
(2) (4)	Lepisosteus osceus	longnose gar
(2)	Amia calva	bowfin
(1) (2) (4)	Alosa pseudoharengus	American shad
(2)	Alosa sapidissima	alewife
(2)	Dorosoma cepedianum	gizzard shad
(1)	Oncorhynchus kisutch	coho salmon
(2)	Salmo gairdneri	rainbow trout
(2)	Salmo trutta	brown trout
(2)	Salvelinus fontinalis	brook trout
(2)	Salvelinus namaycush	lake trout
(2)	Coregonus artedii	shallowwater cisco
(2)	Coregonus clupeaformis	lake whitefish
(2)	Prosopium cylindraceum	round whitefish
(1) (2)	Osmenus mordox	smelt
(2)	Hiodon tergisus	mooneye
(1) (2) (4)	Umbra limi	central mudminnow
(1) (2) (4)	Esox americanus	grass pickerel
(1) (2) (4)	Esox lucius	northern pike
(1) (2) (4)	Esox masquinongy	muskellunge
(2) (4)	Campostoma anomalum???	stoneroller
(1) (2)	Carassius auratus	goldfish
(1) (2)	Chrosomus eos	redbelly dace
(2)	Couesius plumbeus	lake chub
(1) (2) (4)	Cypninus caopio	carp
(4)	Hybopsis storeriana	silver chub
(1) (4)	Nocomis bizuttatus	hornyhead chub
(1) (2) (4)	Nocomis micropogon	river chub

Source	Scientific Name	Common Name
(1) (2) (4)	Notemizonus crysoleucos	golden shiner
(1) (2) (3) (4)	Notropis cornutus	common shiner
(4)	Notropis dorsalis???	bigmouth shiner
(4)	Notropis heteroden	blackchin shiner
(1) (2) (3) (4)	Notropis heterolepis	blacknose shiner
(1) (2) (3) (4)	Notropis hudsonius	spottail shiner
(4)	Notropis rebellus	rosyface shiner
(1) (2) (4)	Notropis spilopterus	spotfin shiner
(2) (4)	Notropis stramineus	sand shiner
(1)	Notropis volucellus	nimic shiner
(1) (2) (3) (4)	Pimephales notatus	bluntnose minnow
(1) (2) (3) (4)	Pimephales promelas	fathead minnow
(1) (3) (4)	Rhinichthys stratulus	slacknose dace
(2) (4)	Rhinichthys cataractae	longnose dace
(1) (2) (3) (4)	Semotilus atromaculatus	creek chub
(2)	Semotilus margarita	pearl dace
(2)	Carpiodes cyprinus	quillback carpsucker
(2) (3)	Catostomus catostomus	longnose sucker
(1) (2) (4)	Catostomus cmmersoni	white sucker
(1) (2)	Erimuzon sucetta	lake chubsucker
(1) (2) (4)	Hypentelium nigricans	hog sucker
(1)	Moxostoma sp.	redorse species
(4)	Moxostoma anisunum	silver redhorse
(2) (4)	Moxostoma macrotepedotum	northern redhorse
(1) (2)	Ictalunus natalis	yellow bullhead
(1) (2) (4)	Ictalunus nekulosis	brown bullhead
(2) (4)	Ictalunus punctatus	channel catfish
(4)	Notunus flavus	stonecat
(1) (2) (4)	Notunus zyrinus	tadpole madtom
(2)	Notunus miurus	brindled madtom
(2) (4)	Anquilla rostrata	american eel
(1) (2) (4)	Fundulus diaphanus	banded killifish

(2)	Lota bota	burbot
(2)	Labidesthes sicculus	brook silversides
(1) (2) (4)	Culaea inconstans	brook stickleback
(1) (2) (4)	Gasterosteus aculeatus	threespine stickleback
(1) (2) (4)	Percopses omiscomaycus	trout-perch
(3)	Morone americana	white perch
(1) (2) (3) (4)	Morone chrysops	white bass
(1) (2) (4)	Ambloplites rupestris	rock bass
(1) (2) (4)	Lepomis gibbosus	pumpkinseed
(2)	Lepmis megalotis	longear sunfish
(1) (2) (4)	Micropterus dolomieui	smallmouth bass
(1) (2) (4)	Micropterus salmoides	largemouth bass
(1) (2)	Pomoxis annularis	white crappie
(1) (2)	Pomoxis nigromaculatus	black crappie
(1) (2) (3) (4)	Perca flavescens	yellow perch
(2)	Stizostedion canadense	sauger
(2) (3) (4)	Stizostedion vitreum	walleye
(2) (4)	Etheostoma blennioides	greenside darter
(2) (4)	Etheostoma caeruleum	rainbow darter
(1)(2) (4)	Etheostoma exile	iowa darter
(4)	Etheostoma flabellane	fantail darter
(1) (2) (3) (4)	Percina caprodes	logperch
(4)	Percina maculata	blackside darter
(2) (3) (4)	Aplodinotus grunniens	sheephead
(2) (4)	Cottus bairdi	nottled sculpin
(2)	Cottus ricei	spoonhead sculpin

(1) Species taken by ROM and OMNR 1957-1974.
(2) Species collected by A. R. Mumma, conservation officer, Ontario 1958.
(3) Older ROM records - card catalogue prior to 1957.
(4) Species recorded on American side as given in the NY state biological survey before 1928.

Fishes from the offshore waters of

Lake Ontario (From Larsen and O'Gorman, 1972)

Species	Frequency	Species	Frequency
Alewife	A	Lake Whitefish	R
American eel	R	Pumpkinseed	R
Bloater	R	Smelt	A
Brown bullhead	R	Redhorse	R
Burbot	R	Rock bass	0
Carp	C	Slimy sculpin	A
Channel catfish	R	Smallmouth bass	0
Chinook	R	Spottail shiner	C
Coho	R	Stonecat	R
Emerald shiner	0	Threespline stickleback	C
Gizzard shad	0	Trout-perch	C
Goldfish	0	Walleye	R
Golden shiner	R	White bass	0
Johnny darter	C	White perch	C
Lake chub	0	White sucker	C
Lake herring	R	Yellow perch	C

A = Abundant; C = common; 0 = occasional; R = rare

Fishes of the inshore waters of Lake Ontario

(Hartman, Van Meter, Wolfert, and Busch, 1972)

Species	Frequency	Species	Frequency
Sea Lamprey	0	Black redhorse	R
Bowfin	0	Silver redhorse	R
Longnose gar	R	Brown bullhead	A
American eel	C	Channel catfish	0
Alewife	A	Stonecat	C
Gizzard shad	C	Trout-perch	C
Lake whitefish	R	Burbot	R
Chinook	R	Banded killifish	R
Coho	R	Silverside	R
Splake	R	Brook stickleback	R
Smelt	C	Threespine stickleback	C
Northern pike	C	White perch	A
Muskellunge	R	White bass	R
Goldfish	0	Pumpkinseed	A
Lake chub	0	Rock bass	A
Carp	C	Bluegill	0
Golden shiner	C	Largemouth bass	0
Emerald shiner	C	Smallmouth bass	A
Common shiner	0	Black crappie	0
Spottail shiner	0	White crappie	R
Spotfin shiner	C	Johnny darter	C
Bluntnose minnow	C	Fantail darter	R
Fathead minnow	0	Yellow perch	A
Blacknose dace	R	Walleye	R
Longnose dace	R	Logperch	0
Creek chub	R	Freshwater drum	R
Quillback	R	Slimy sculpin	R
White	C	Mottled sculpin	R

A = abundant; C= common; 0 = occasional; R = rare.

ANNEX 9

FISH SPECIES BY SPAWNING AREA, NURSERY AREA, FEEDING AREA, OVERWINTERING AREA AND MIGRATION AREAS

A list of species by critical area and habitat type
Species by spawning area
(From Hartley and Van Vooren, 1977)

shallow protected, sand-mud, silt with vegetation	shallow protected, sand-mud, silt without vegetation	shallow exposed rock-rubble	shallow exposed gravel-sand	rubble gravel, with current	mid-water
banded killifish	black bullhead	channel catfish	alewife	burbot	emerald shine
bigmouth buffalo	bluegill sunfish	fantail darter	channel darter	freshwater drum	freshwater dr
black bullhead	bluntnose minnow	freshwater drum	e. sand darter	sauger	silver chub
black crappie	bowfin	johnny darter	freshwater drum	smelt	
blacknose shiner	brindled madtom	rock bass	gizzard shad	walleye	
bluegill sunfish	brook silversides	sauger	logperch	white bass	
bluntnose minnow	brown bullhead	smallmouth bass	sand shiner	whitefish	
bowfin	carp	stonecat	spottail shiner	yellow perch	
brindled madtom	fathead minnow	yellow perch	troutperch		
brook silversides	goldfish		white crappie		
brown bullhead	green sunfish		white perch		
carp	Iowa darter		yellow perch		
central mudminnow	largemouth bass				
fathead minnow	longnose gar				
golden shiner	mimic shiner				
goldfish	mottled sculpin				
grass pickerel	pumpkinseed sunfish				
green sunfish	spotfin shiner				
gr. side darter	spotted gar				
Iowa darter	white crappie				
lake chubsucker	yellow bullhead				
largemouth bass					
muskellunge					
northern pike					
pugnose shiner					
pumpkinseed sunfish					
quillback					
spotfin shiner					
yellow bullhead					

Species by nursery area

shallow protected, sand, mud, silt with vegetation	shallow protected, sand, mud, silt without vegetation	shallow exposed rock and rubble	shallow exposed gravel and sand	medium mud	rubble-gravel, with current
banded killifish	black bullhead	channel catfish	alewife	bigmouth buffalo	stone cat
black bullhead	bluegil sunfish	fantail darter	channel catfish	carp	
black crappie	bluntnose minnow	lake sturgeon	channel darter	channel catfish	
blacknose shiner	brindled madtom	mottled sculpin	freshwater drum	freshwater drum	mid water
bluegill sunfish	brook silversides	rock bass	gizzard shad	gizzard shad	
bluntnose minnow	brown bullhead	spotfin shiner	johnny darter	goldfish	emerald shiner
bowfin	carp	stonecat	logperch	lake sturgeon	freshwater drum
brindled madtom	channel catfish	white bass	sand darter	stonecat	smelt
brook silversides	fathead minnow	white sucker	sand shiner	troutperch	
brown bullhead	gizzard shad	yellow perch	sauger	white bass	deep
carp	goldfish		spotfin shiner	white crappie	gravel-sand
central mudminnow	green sunfish		spottail shiner		
channel catfish	largemouth bass		troutperch		freshwater drum
channel darter	pumpkinseed sunfish		walleye		smelt
fathead minnow	smallmouth bass	rubble-gravel,	white bass		troutperch
gizzard shad	spotfin shiner	with current	white perch		
golden shiner	white crappie		white sucker		deep mud
goldfish	yellow perch	stone cat	yellow perch		
grass pickerel	yellow perch				freshwater drum
green sunfish					troutperch
gr. sided darter					
Iowa darter					
lake chubsucker					
largemouth bass					
longnose gar					
logperch					
muskellunge					
northern pike					
pugnose shiner					
pumpkinside sunfish					
quillback					
spotfin shiner					
spotted gar					
tadpole madtom					
yellow bullhead					

Species by feeding area

shallow protected, sand, mud silt with vegetation	shallow protected, sand, mud silt without vegetation	nearshore exposed rock-rubble	nearshore exposed gravel-sand	nearshore exposed mud bottom	offshore rock-rubble
banded killifish	bigmouth buffalo	brown trout	bigmouth buffalo	bigmouth buffalo	channel catfish
bigmouth buffalo	black bullhead	carp	brown bullhead	brown bullhead	chinook salmon
black bullhead	bluegill	channel catfish	brown trout	carp	coho calmon
black crappie	bluntnose minnow	channel darter	carp	channel catfish	freshwater drum
blacknose shiner	brindled madtom	chinook salmon	channel catfish	freshwater drum	lake sturgeon
bluegill	brook silversides	coho salmon	channel darter	goldfish	sauger
bluntnose minnow	brown bullhead	fantail darter	chinook salmon	quillback	spottail shiner
bowfin	carp	freshwater drum	coho salman	spottail shiner	stonecat
brindled madtom	fathead minnow	golden redhorse	fantail darter	troutperch	walleye
brook silversides	goldfish	mottled sculpin	freshwater drum	white sucker	white bass
brown bullhead	green sunfish	rock bass	golden redhorse		yellow perch
carp	largemouth bass	sauger	johnny darter		
central mudminnow	mimic shiner	silver redhorse	lake sturgeon	**offshore gravel-sand**	**pelagic, central basin**
fathead minnow	pumpkinseed	smallmouth bassd	logperch		
golden shiner	quillback	spottail shiner	quillback		
goldfish	sauger	stonecat	sand darter	freshwater drum	chinook salmon
grass pickerel	white crappie	walleye	sand shiner	johnny darter	coho salmon
green sunfish	yellow bullhead	white bass	sauger	lake sturgeon	emerald shiner
greensided darter		white sucker	silver redhorse	logperch	silver chub
Iowa darter		yellow perch	spotfin shiner	spottail shiner	smelt
lake chubsucker			spottail shiner	troutperch	
largemouth bass			stonecat	walleye	**general central basin**
longnose gar			troutperch	yellowperch	
muskellunge			walleye		
northern pike			white bass	**offshore mud bottom**	burbot
pugnose shiner			white crappie		longnose sucker
pumpkinseed			white perch		spotted sucker
quillback			white sucker	freshwater drum	whitefish
spotted gar			yellow perch	spottail shiner	yellow perch
tadpole madtom				troutperch	
white crappie				**pelagic, western basin**	
yellow bullhead					
				alewife	
				emerald shiner	
				gizzard shad	
				silver chub	

Species by migration area

in and out of small tributaries	in and out of large tributaries	in and out from nearshore	in and out from offshore reefs	in and out of Maumee Bay and Sandusky Bay	along shore	offshore to and from deep water
alewife	bigmouth bullfal	alewife	burbot	channel catfish	coho salmon	alewife
bigmouth buffalo	brown trout	bigmouth buffalo	channel catfish	freshwater drum		freshwater drum
black bullhead	carp	burbot	freshwater drum	sauger		gizzard shad
brown bullhead	channel catfish	carp	sauger	walleye		lake sturgeon
carp	coho salmon	channel catfish	spottail shiner	white bass		smelt
channel catfish	freeshwater drum	emerald shiner	stonecat	yellow perch		whitefish
coho salmon	gizzard shad	freshwater drum	walleye			
gizzard shad	golden redhorse	gizzard shad	white bass			
golden redhorse	goldfish	goldfish	yellow perch			
goldfish	grass pickerel	mottled sculpin				
grass pickerel	lake sturgeon	northern pike				
northern pike	northern pick	quillback				
northern redhorse	northern redhorse	smallmouth bass				
quillback	quillback	sauger				
rainbow trout	rainbow trout	spottail shiner				
silver lamprey	sauger	troutperch				
silver redhorse	silverlamprey	walleye				
smelt	silver redhorse	whitefish				
white bass	smallmouth bass	yellow perch				
white sucker	walleye					
yellow bullhead	white bass					
	white perch					
	white sucker					

Species by overwintering area

protected with vegetation	protected without vegetation	deep mud bottom adjacent to island reefs	50 ft. and deeper	nearshore rock and rubble	nearshore gravel and sand
banded killifish	black bullhead	carp	freshwater drum	alewife	alewife
black bullhead	bluegill sunfish	channel catfish	gizzard shad	channel darter	channel darter
black crappie	bluntnose minnow	gizzard shad	sand shiner	emerald shiner	emerald shiner
blacknose shiner	brindled madtom	goldfish	spottail shiner	fantail darter	johnny darter
bluegill sunfish	brook silversides	rock bass	troutperch	logperch	logperch
bluntnose minnow	brown bullhead	stonecat	white bass	mottled sculpin	smelt
bowfin	emerald shiner	walleye	white sucker	sand darter	yellow perch
brindled madtom	fathead minnow			smallmouth bass	
brook silversides	green sunfish			yellow perch	
brown bullhead	largemouth bass				
central mudminnow	mimic shiner				
fathead minnow	pumpkinseed sunfish	**reefs and shoals of the island area**	**heated effluent**	**nearshore mud bottom**	**deeper water of the western basin**
grass pickerel	spotfin shiner				
gr. sided darter	white crappie				
green sunfish	yellow bullhead				
Iowa darter		alewife	alewife	bigmouth buffalo	channel catfish
lake chubsucker		burbot	coho salmon	brown bullhead	freshwater drum
largemouth bass		coho salmon	gizzard shad	carp	golden redhorse
longnose gar		sauger		goldfish	northern redhorse
northern pike		whitefish		quillback	silver redhorse
pugnose shiner		yellow perch			spottail shiner
pumpkinseed sunfish					troutperch
spotfin shiner					walleye
spotted gar					white bass
tadpole madtom					white sucker
white crappie					
yellow bullhead					

ANNEX 10

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ANNEX 11

List Of Participatants In Water Quality, Wildlife/Wetlands, And Fish Resources Evaluation.

Name	Agency	Participation
Angle, E.	Ohio, DNR, Columbus	General
Beaulieu, T.	Canada, DFO, Burlington	General
* Bien, W.	Canada, DOE, IWD, Burlington	General
* Bewick, P.	Ontario, MNR, London	General, Fish Section Leader
**Brown, D.F.	U.S., FWS, Harrisburg	General, Wildlife Section Leader
**Brown, J.	U.S., ACOE, Buffalo	General, Beaches and Boating Section Leader
**Burton, T.	Ontario, MNR, London	General Beaches Section Leader
**Busch, W.D.	U.S., FWS, Harrisburg	Co-Chairperson, Fish Section Leader
**Cheng, C.	Canada, DOE, IWD, Bur.	Co-Chairperson, Water Quality Quality Sect.Leader
Collis, J.	U.S., ACOE, Detroit	General
*Emery, L.	U.S., FWS, Columbus	General, Fish Section Leader
Frapwell, P.	U.S., ACOE, Buffalo	General
Gillespie, D.	Canada, DOE, IWD, Ottawa	General
**Guido, R.	U.S., ACOE, Buffalo	General, Beaches and Boating Sect.Leader
*Haas, R.	Mich, DNR, Mt. Clemens	General
*Holder, A.	Ontario, MNR, London	General
Hore, R.	Ontario, MOE, Toronto	General
**Johnson, H.	Canada, Sea Lamprey Con. Centre, Sault Ste. Marie	General, Fish Sec. Leader
*Kenyon, R.	Pennsylvania Fish Comm. Fairview	General
**Krakowski, E.	Canada, DOE, IWD, Bur.	Gen., Water Qual.Section Leader, General Editor
Kulp, C.	U.S., FWS, State College,PA	General
LeFeuvre, A.R.	Canada, DOE, IWD, Bur.	General
Marshall, M.	Ontario, MNR, London, CWS	General
**McCullough, G.	Canada, DOE, CWS, London	General, Wildlife Section Leader

ANNEX 11 (CONTINUED)

Name	Agency	Participation
	U.S., ACOE, Detroit	General
*Oberst, R.	U.S., FWS, East Lansing	General, Co-Chairman
Pearce, W.	New York, DEC, Cape Vincent	General
**Potos, C.	U.S., EPA/ACOE, Chicago	General, Water Quality Section Leader
Scholl, R.	Ohio, LDNR, Columbus	General
*Shepherd, W.	New York, DEC, Olean	General
Tibbles, J.	Canada, Sea Lamprey Control Centre, Sault Ste. Marie	General
**Urisk, J.	Canada, DOE, IWD, Burlington	Co-Chairperson, General Editor
*Vogel, T.	Ohio, DNR, Columbus	General
Williamson, B.	U.S., ACOE, Detroit	General

* Active participation during portions of the writing or editing of the various draft documents.

** Activity wrote and/or edited various sections or all draft documents.

ANNEX 12

CONVERSION FACTORS

(BRITISH TO METRIC UNITS)

1 cubic foot per second (cfs) = 0.028317 cubic metres per second (cms)

1 cfs-month = 0.028317 cms-month

1 foot = 0.30480 metres

1 inch = 2.54 centimetres

1 mile (statute) = 1.6093 kilometres

1 ton (short) = 907.18 kilograms

1 square mile = 2.5900 square kilometres

1 cubic mile = 4.1682 cubic kilometres

Temperature in Celsius: $°C = (°F - 32)/1.8$

1 acre-feet = 1,233.5 cubic metres

1 gallon (U.S.) = 3.7853 litres

1 gallon (British) = 4.5459 litres